WATER EFFICIENCY, CONSERVATION AND REUSE FOR HOKULANI ELEMENTARY SCHOOL

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ABSTRACT

In Hawaii and around the world, urbanization has led to an increase in water usage around the world. As we begin to face issues such as climate change and sea level rise in Hawaii, the need to conserve water resources becomes increasingly important. Although we live on an island surrounded by water, we still face water issues and must begin to make changes in order to conserve the resources that we have. Over the coming years, Hawaii will face water problems associated with scarcity, pollution, climate change as well sea level rise.

This paper investigates water efficiency, water conservation and water reuse to produce a list of strategies that can be used to help and guide administrators, designers, and architects to choosing the right water reduction strategies for their project. In addition, the paper also provides a set of guidelines that can be applied to educational institutions in Hawaii. These guidelines set water reduction goals and list strategies for reaching these goals. Two case studies are analyzed and used to demonstrate how these water reduction strategies are used by other school in Hawaii.

The design portion of the paper focuses on the redesign of Hokulani Elementary School. The design analyzes water use and implements water reduction strategies such as water efficient fixtures as well as low impact development strategies and water reuse systems. The thesis is a comprehensive review of water reduction strategies that can be applied to school buildings in Hawaii.

Acknowledgements

I dedicate this thesis to everyone in my life, especially those that are not with us today.

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1. Introduction

1.1 Statement of Problem

1.1.1 Introduction

Water covers approximately 70 percent of the Earth's surface, but less than 1 percent of that is available for human use.[1] Urbanization has led to an increase in water usage around the world. As we begin to face issues such as climate change and sea level rise in Hawaii, the need to conserve water resources becomes increasingly important. Urbanization has led to an increase in impervious surfaces that in turn affects how water moves above and below ground during and following storm events. This also affects the quality of that storm water and the water bodies that the storm water is directed to.[2] Although we live on an island surrounded by water, we still face water issues and must begin to make changes in order to conserve the resources that we have. Over the coming years, Hawaii will face water problems associated with scarcity, pollution, climate change as well sea level rise.

1.1.2 Water Scarcity

Although many of us take water for granted, water is part of our lives every day and affects our health, economy and environment. However, many of us use water excessively even though our supply is finite. For so long water was a plentiful resource that was used freely in most areas, the situation is now changing to where water scarcity has become a threat to food scarcity, human health and natural ecosystems.[3] The average American uses 100 gallons of water every day.[4] We can reduce our water use by as much as 30 percent by taking simple steps such as installing high efficiency plumbing fixtures and using water efficiently in our yards.[5] In addition to our overconsumption we also face other problems like pollution, climate change and sea level rise which puts added stress on our water supply here in Hawaii. We have a limited amount of freshwater-less than 1 percent of all that's available on the planet- and we must share this supply among the 6.7 billion inhabitants of the planet.[6] This amount of water will not change, the number of people we must provide for, however, is continuously growing at a rapid rate. In addition to a rise in population, there is also a rise in the standard of living which also increases water consumption.

[1] "Water Supply and Use in the United States." Accessed October 21, 2016. https://www3.epa.gov/watersense/docs/ws_supply508.pdf.
[2] National Academies Press and National Research Council. Urban Stormwater Management in the United States. National Academies Press, 2009.
[3] Seckler, David, David Molden, and Randolph Barker. Water Scarcity of the Twenty-First Century. PDF. Colombo,Sri Lanka: International Water Management Institute, March 1999.
[4] "Conservation." Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation.
[5] "WaterSense Labeled Products." WaterSense. 2016. Accessed October 21, 2016. https://www3.epa.gov/watersense/products/index.html.
[6] Rogers, Peter P., and Susan Leal. Running out of Water: The Looming Crisis and Solutions to Conserve Our Most Precious Resource. New York: Palgrave Macmillan, 2010.

Since we live on an island many of us take water for granted. Our primary source of drinking water is groundwater, which is freshwater that is filtered through mountain watersheds and held within the porous volcanic rock of the island.[7] This water supply is a resource that should be used wisely as our supply is limited with a growing population that's demands will soon outweigh the supply. Since Hawaii relies heavily on groundwater, we must be mindful of the sustainable yield. Sustainable yield of water resources can be defined as the ecological yield that can be extracted without reducing the base of the water supply itself. Thus, sustainable yield for water resources depends upon water that is being extracted from the aquifers and the rate at which water is being recharged into the aquifer.

1.1.3 Water Pollution

In addition to contributing to water scarcity, urbanization has also influenced water pollution. Urbanization has changed the land use from forest or agricultural uses to suburban and urban use. These changes in land use have resulted in an increased area of impervious surfaces. This in turn affects the way that water moves above and below ground during and following storm events, the quality of that storm water and the condition of the nearby lakes, rivers and estuaries.[8] Storm water runoff from the built environment has become one of the great challenges in water pollution control as it is the main contributor to water quality problems.

Land use and land cover are greatly altered during urbanization. The introduction of buildings, roads and urban infrastructure have also altered the hydrology of the area leading to water quality degradation and different water flows.[9] The increase of impervious surfaces means that the amount of land area that is available for infiltration is reduced and the amount of storm water available for direct surface runoff is increased.[10] This reduced infiltration can result in an overflow of water to the storm water systems as well as increasing the severity and frequency of flooding. Rainfall that is unable to be infiltrated then flows quickly over surfaces such as roads and rooftops picking up pollutants that then enter storm drains or ditches. Many times, these polluted waters are then emptied into local waterways without treatment.

1.1.4 Climate Change

Hawaii will undoubtedly face effects of climate change and this will affect nearly if not all aspects of life in Hawaii. Some changes that are already being experienced and monitored include carbon dioxide concentration rising, surface air temperature rising, sea level rising, sea-surface temperature rising, upper ocean heat content rising, ocean

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[7]"Water Supply and Use in the United States." Accessed October 21, 2016. https://www3.epa.gov/watersense/docs/ws_supply508.pdf.

[8] National Academies Press and National Research Council. Urban Stormwater Management in the United States. National Academies Press, 2009.

[9] National Academies Press and National Research Council. Urban Stormwater Management in the United States. National Academies Press, 2009.

[10] National Academies Press and National Research Council. Urban Stormwater Management in the United States. National Academies Press, 2009.

chemistry changing, rainfall amount and distribution changing, stream base flow decreasing, winds and waves changing, extremes are changing, and habitats and species are changing.[11]

Figure 1: Indicators of Climate Change in Pacific Region[12]

In addition, climate change will affect our water quantity, quality, timing and distribution.[13] Rising air and ocean temperatures, rainfall patterns, sea level rise and changing ocean chemistry are a few of the effects that Hawaii will experience. Seasonal differences that will occur in precipitation, water flows and demand means that water will not always be available when and where it is needed.[14] These changes will impact the ability of urban systems to meet water demands and in turn these urban systems are producing greenhouse gases that influence and enhance climate change.

Climate change will also result in higher water temperatures, increased precipitation intensity, and longer periods of flow that will increase many forms of water

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[11] Keener, Victoria W. Climate Change and Pacific Islands: Indicators and Impacts: Case Studies from the 2012 Pacific Islands Regional Climate Assessment (PIRCA). Washington, DC: Island Press, 2012.
[12] Keener, Victoria W. Climate Change and Pacific Islands: Indicators and Impacts: Case Studies from the 2012 Pacific Islands Regional Climate Assessment (PIRCA). Washington, DC: Island Press, 2012.
[13] Climate Change and Water. PDF. Washington, D.C.: USDA, June 2008.
[14] Climate Change and Water. PDF. Washington, D.C.: USDA, June 2008.

pollution including sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt and thermal pollution. This will in turn impact ecosystems, human health, and the reliability and operating costs of water systems.[15] Reducing water use can have multiple benefits by reducing water usage as well as decreasing greenhouse gases produced by urban water systems.

Over the past century, rainfall has decreased throughout Hawaii. One precipitation scenario for Hawaii for the 21st century is a 5% to 10% reduction for the wet season and a 5% increase in the dry season.[16] In addition, Hawaii is experiencing a trend toward fewer extreme rainfall events and a prosperity toward longer dry periods.[17] These changes will mean that freshwater supplies will become more limited on the islands. Food security will also be affected if prolonged drought threatens food production and productivity as well as if storm events damage critical infrastructure. The need for us to conserve our water resources is rapidly increasing.

1.1.5 Sea Level Rise

Over the past century, the burning of fossil fuels as well as other activities have released enormous amounts of heat trapping gases into the atmosphere causing the Earth's surface temperature to rise and the oceans to absorb about 80 percent of this additional heat.[18]When water heats up it expands and much of sea level rise is attributable to warmer oceans expanding and occupying more space. Since the 1970s, sea surface temperature has increased at a rate of 0.13 degrees to 0.41 degrees Fahrenheit per decade.[19] Because of climate change, Hawaii will also experience sea level rise. Global sea levels have risen through the 20th century and sea level is only rising faster in response to ocean warming and glaciers melting. Scientific research has indicated that sea levels worldwide have been rising at a rate of 0.14 inches per year since the early 1990s.[20] This trend is linked to global warming and puts coastal communities such as Hawaii at risk of being claimed by the ocean.

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[15] Younos, Tamim M., and Caitlin A. Grady. Climate Change and Water Resources. New York: Springer, 2013.

[16] Keener, Victoria W. Climate Change and Pacific Islands: Indicators and Impacts: Case Studies from the 2012 Pacific Islands Regional Climate Assessment (PIRCA). Washington, DC: Island Press, 2012.

[17] Keener, Victoria W. Climate Change and Pacific Islands: Indicators and Impacts: Case Studies from the 2012 Pacific Islands Regional Climate Assessment (PIRCA). Washington, DC: Island Press, 2012.

[18] "Sea Level Rise." Oceans Levels Are Getting Higher-Can We Do Anything About It? Accessed October 21, 2016. http://ocean.nationalgeographic.com/ocean/critical-issues-sea-level-rise/.

[19] Keener, Victoria W. Climate Change and Pacific Islands: Indicators and Impacts: Case Studies from the 2012 Pacific Islands Regional Climate Assessment (PIRCA). Washington, DC: Island Press, 2012.

[20] "Sea Level Rise." Oceans Levels Are Getting Higher-Can We Do Anything About It? Accessed October 21, 2016. http://ocean.nationalgeographic.com/ocean/critical-issues-sea-level-rise/.

Figure 2: Honolulu Sea Level Rise Scenario: 4 ft. Above Modern MHHW Tidal Surface[21]

Being an island, Hawaii is at increased impact of sea level rise with a number of coastal communities that will be directly affected. Increased flooding, erosion, and saltwater intrusion are some of the effects that Hawaii will face as a result of sea level rise. The proximity of human settlements and major infrastructure to the ocean only increases the vulnerability of the Pacific islands. In addition, since the islands are almost entirely dependent on imported food, fuels, and materials, the vulnerability of ports and airports to increases in sea level and extreme events is of great concern.[22]

Freshwater supplies are already constrained on the islands and this supply will become more limited on many islands due to saltwater intrusion associated with sea level rise. Salt water intrusion into our groundwater will reduce the quantity and quality of freshwater in coastal aquifers. Coastal flooding and erosion will also damage coastal ecosystems, infrastructure and agriculture. The possibility of increased temperatures in

[21] Lim, Siang-Chyn, and Dr. Charles Fletcher Chip Fletcher. "Sea Level Rise Website." SLR Scenarios. Accessed November 20, 2016. http://www.soest.hawaii.edu/coasts/sealevel/HawaiianIslands.html.
[22] Keener, Victoria W. Climate Change and Pacific Islands: Indicators and Impacts: Case Studies from the 2012 Pacific Islands Regional Climate Assessment (PIRCA). Washington, DC: Island Press, 2012.

addition to decreased rainfall will reduce the amount of freshwater that will be available for drinking and irrigation.[23]

1.1.6 Conclusion

Issues such as water scarcity, pollution, climate change, and sea level rise are threatening the water supply of Hawaii. This makes it important to conserve the resources that we have. Water is a finite resource that is limited especially since we live on an island. By taking steps to improve efficiency, reuse and conserve water use we can in turn begin to conserve water for the future generations. Preserving and conserving water is imperative not only to health but also our economic future.[24] In addition, using less water also means using less electricity which in turn results in a decrease in greenhouse gases. Greenhouse gases influence climate change which affects temperature, rainfall patterns, as well as creating periods of drought and flooding. By conserving water and improving efficiency we can begin to mitigate these problems.

1.2 Objective

The objective of this paper is to give designers as well as people in the community, a better idea of how we can begin saving water. This thesis will not only provide an overview of how to begin to save water by conserving and reusing, but also propose a set of design guidelines specifically geared towards schools. This set of guidelines will outline different options and strategies that can be used to reuse, conserve, and use water efficiently.

1.3 Purpose of Study

The purpose of this research is to give an outline of how we can conserve and reuse water in an urban setting, more specifically in K-12 school buildings. The design proposal will be for suggestions on how to improve water efficiency, conservation, and reuse in Hokulani Elementary School. This thesis will provide design suggestions on how we can begin to improve efficiency, reuse and conserve our water resources that are quickly declining. By looking at case studies in other states, we can begin to gather strategies to use in Hawaii that can be tailored to our climate, landscape, and culture.

1.4 Significance of Research

This research is important because it will give suggestions for water reuse, conservation and efficiency strategies specifically geared towards schools. These guidelines can be used to improve water efficiency and reduce water use in schools. This can help schools to save water, but also provide opportunities for the students to learn more about water use. These lessons can be translated into classrooms activities that will help the students to gain a better understanding and hopefully use within their homes.

[23] "National Climate Assessment." 2014. Accessed October 21, 2016. http://nca2014.globalchange.gov/.
[24] "Water Supply and Use in the United States." Accessed October 21, 2016. https://www3.epa.gov/watersense/docs/ws_supply508.pdf.

2. Methodology

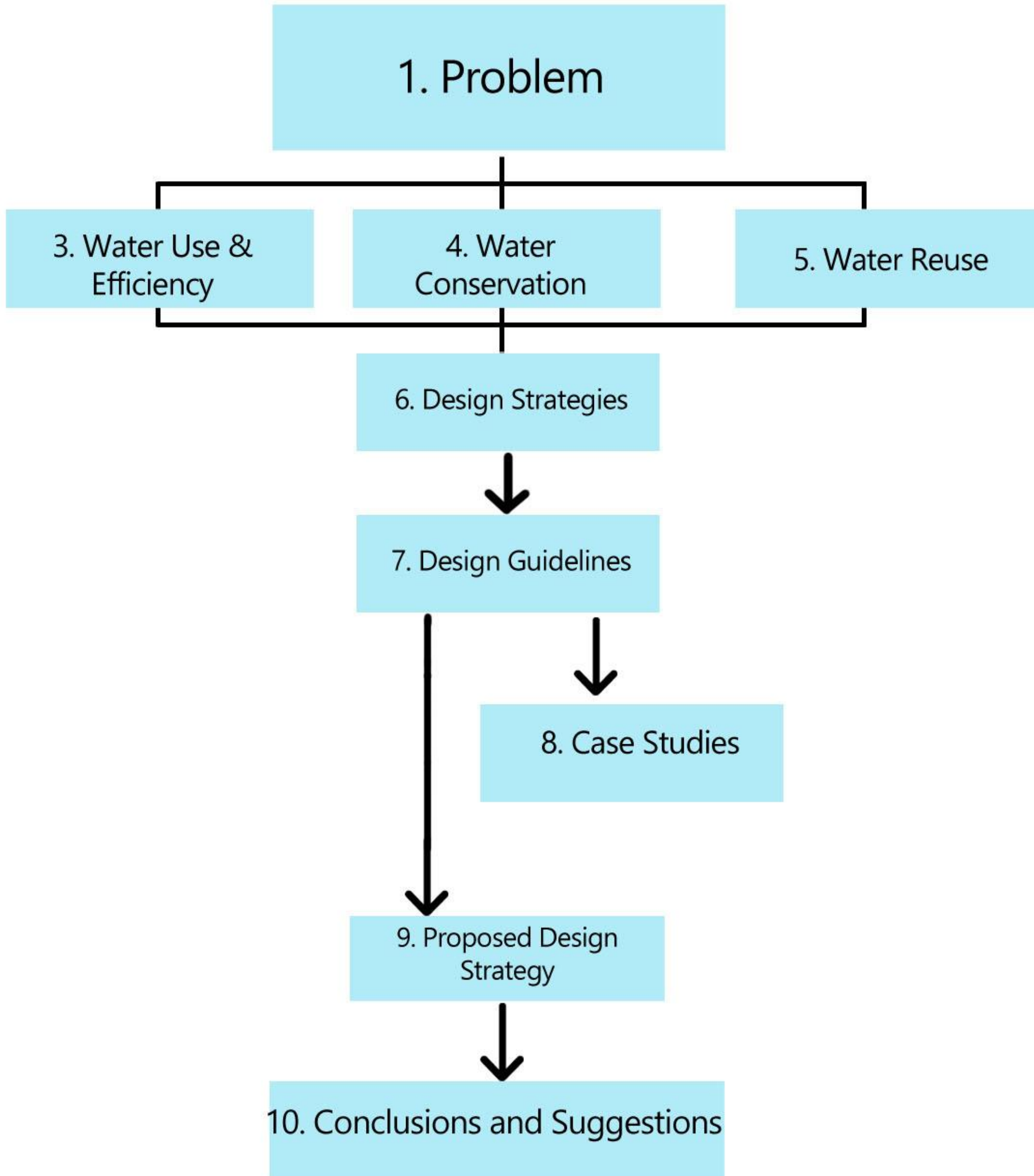

Figure 3: Diagram of Methodology[25]

The first part of the paper will introduce the problems we are currently facing in the water sector as well as outlining the purpose and significance of the research. By

[25] Made by Author.

understanding the problems that we face, we can begin to form a solution that addresses all aspects of the problem.

The thesis will also look at how we currently use water and how we can make these practices more efficient. In addition to efficiency, this paper will also look at conservation. The paper will research how we can begin to conserve and reuse water within the urban landscape in an educational setting. By employing strategies such as green technologies and water efficient appliances, we can begin to conserve our water resources.

The paper will also have a section dedicated to design strategies. This portion will outline different strategies and address how each of these strategies can be used in different projects. The design strategies will also look at costs and benefits for each strategy as well as life cycle and maintenance costs.

In addition, the paper will also have a section for design guidelines. This section will provide an outline of how to incorporate the design strategies. The guidelines set goals for schools to achieve in terms of water reduction and shows ways that the reduction goals can be met.

The paper will then look at two case studies in the United States to look at how water reuse and conservation is achieved in other projects. The case studies will be of Hawaii Preparatory Academy and Hawaii Community College Palamanui campus.

The paper will then propose a design for a site in Hawaii. The design suggestions will be geared towards Hokulani Elementary School. This design will take into consideration aspects such as site, landscape, infrastructure, water usage, and reuse in buildings. The result will be a comprehensive solution for water efficiency, reuse, and conservation for school buildings.

3. Water Use and Efficiency

3.1 Introduction

Figure 4: Hawaii Water Cycle[26]

Hawaii's freshwater supply is dependent upon the water cycle. Naturally occurring activities in the atmosphere play vital roles in our atmosphere. It is important for us to understand how the water cycle works, to begin to understand how we can use water more wisely. Hawaii's freshwater supply and climate are dependent upon trade winds, which blow across subtropical regions of the Pacific Ocean much of the year. In the Northern Hemisphere, trade winds blow from the northeast, bringing mild days and nights and an abundance of moisture to land masses like Oahu.[27] These trade winds pick up moisture as they travel across the ocean. On Oahu, these winds arrive from the northeast, on the windward side, and are deflected upward when they reach the Koolau Mountains. These mountains play a vital role in assuring abundant rainfall for the island. As the moist air that is deflected from the mountains rises near the mountain tops, it cools, forms clouds and then condenses and falls as rain to the ground.[28]

[26] "Polyad Hawaii Tours Blog." Where Does Hawaii's Natural Water Reserve Come From? | Gray Line Hawaii Travel & Activities Blog. Accessed November 18, 2016. http://polyadhawaiitours.com/blog/where-does-hawaiis-natural-water-reserve-come-from/.
[27] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.
[28] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.

In a normal year, about two billion gallons of rain falls on Oahu every single day.[29] Almost a third replenishes the island's aquifer, another third nourishes vegetation and evaporates and a third is discharged as runoff into the ocean.[30] Most of Oahu's precipitation occurs on the peaks and slopes of the Koolau Mountains. An average of more than 250 inches of rain falls upon this range each year. The leeward side, Waianae Mountains, receive comparatively less moisture. The Waianae range is in the "rain shadow" of the Koolau Mountains, which means the Koolau Mountains blocks and captures most of the moist air that moves along Oahu's windward side.

Ground water is one of Hawaii's most important natural resources and provides about 99% of Hawaii's domestic water and about 50% of all freshwater used in the State.[31] Groundwater has a variety of uses in Hawaii which includes drinking water, irrigation, and meeting domestic, commercial and industrial demands. Groundwater resources can become limited by factors such as water quality, environmental and economic concerns.

Water that is beneath the ground surface occurs in two principal zones: the unsaturated zone and the saturated zone. In the unsaturated zone, the pore spaces in rocks contain both air and water whereas in the saturated zone, the pore spaces are filled with water.[32] The upper space of the saturated zone is referred to as the water table. The water table can be located a foot below the ground's surface or can sit hundreds of feet down.[33] Water that is below the water table is referred to as ground water. The water table can be deep or shallow, depending on various factors such as heavy rains or heavy pumping of groundwater supplies. Groundwater can range in salinity from saltwater to brackish water and freshwater.

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[29] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.

[30] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.

[31] USGS. Ground Water in Hawaii. PDF. Honolulu, HI: USGS, 2000.

[32] USGS. Ground Water in Hawaii. PDF. Honolulu, HI: USGS, 2000.

[33] "What Is Groundwater." Get Informed: The Basics. 2015. Accessed November 18, 2016. http://www.groundwater.org/get-informed/basics/whatis.html.

Figure 5: Oahu Aquifers[34]

The amount of water that is recharged to the aquifers is the volume of rainfall, fog drip and irrigation water that is not lost to runoff or evapotranspiration or stored in soil. Recharge is typically about 10 to 50 percent of the rainfall, fog drip, and irrigation water.[35] Water travels through cracks, crevices and pockets that channel, store and purify water.[36]

In Hawaii, the major fresh groundwater systems are below the lowest water table and are either freshwater lens or dike impounded systems.[37] A freshwater lens system includes a lens shaped freshwater body, an intermediate transition zone of brackish water and underlying salt water. The thickness and concentration of the lens is continually in flux and is affected by natural seasonal influences and pumping or drafting of freshwater to meet the population's needs.[38] The lens shaped body of fresh water that exists within Oahu's porous volcanic rock is called an aquifer or freshwater lens.[39] This water has been

[34] USGS. Ground Water in Hawaii. PDF. Honolulu, HI: USGS, 2000.
[35] USGS. Ground Water in Hawaii. PDF. Honolulu, HI: USGS, 2000.
[36] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.
[37] USGS. Ground Water in Hawaii. PDF. Honolulu, HI: USGS, 2000.
[38] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.
[39] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.

purified by percolating through soil and volcanic rock and is the source of water for many wells and springs. The freshwater lens is held in place by the island's outlying, underwater caprock that reaches inland from the shoreline.[40]

Groundwater in the Hawaiian Islands often becomes trapped in massive vertical compartments that have been formed by volcanic dikes. Dikes are formed when magma stopped flowing to the surface, then cooled over time to form the dense, nonporous rock in vast, miles long sheets aligned vertically in the rift zones.[41] Water escapes the dikes when the water level rises and overflows over the walls of the dike or when internal pressure causes leakage. Freshwater lens systems are recharged by direct infiltration of precipitation and irrigation water and by inflow from up gradient ground water systems.[42]

Water efficiency is the smart use of our water resources through water-saving technologies as well as simple steps that can be taken.[43] Using water efficiently will help to ensure that there are water supplies for today and for future generations.

Figure 6: End Uses of Water in Various Types of Commercial and Institutional Facilities[44]

Buildings consume significant amounts of water and are an area where a significant amount of water savings can occur. Since urbanization has resulted in a rise of

[40] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.
[41] "The Water Cycle." The Water Cycle - Board of Water Supply. Accessed November 18, 2016. http://www.boardofwatersupply.com/water-resources/the-water-cycle.
[42] USGS. Ground Water in Hawaii. PDF. Honolulu, HI: USGS, 2000.
[43] "Educational Facilities." Type of Facilities. Accessed October 21, 2016. https://www3.epa.gov/watersense/commercial/types.html.
[44] "Educational Facilities." Type of Facilities. Accessed October 21, 2016. https://www3.epa.gov/watersense/commercial/types.html.

living standards and building's water use is projected to increase in the coming years. Significant water saving can be achieved indoors and outdoors in equipment and operation practices. The commercial and institutional sectors is the second largest consumer of publicly supplied water in the United States and accounts for 17 percent of the withdrawals from public water supplies.[45] This sector includes facility types such as hotels, restaurants, office buildings, schools, hospitals, laboratories, government and military institutions.

In previous years, water use and efficiency was not a main concern. This fact in combination with wasteful use patterns have resulted in water being used inefficiently in buildings. Water scarcity as well as increased costs, buildings operators and owners are realizing the benefits that are linked to improve water efficiency.

About six percent of total water use in commercial and institutional facilities in the U.S. takes place in educational facilities such as school, universities, museums, and libraries.[46] The primary water use purposes in buildings include: toilets, showers, wash basins, kitchens, laundry, heating, ventilation and air conditioning (HVAC) systems, and landscaping. In educational facilities, the largest uses of water include restrooms and landscaping. Operating costs and environmental impacts are influenced and impacted by water use. Industry estimates suggest that implementing water-efficient practices can decrease operating costs by approximately 11 percent and energy and water use by 10 and 15 percent, respectively.[47]

[45] "Educational Facilities." Type of Facilities. Accessed October 21, 2016. https://www3.epa.gov/watersense/commercial/types.html.

[46] "Educational Facilities." Type of Facilities. Accessed October 21, 2016. https://www3.epa.gov/watersense/commercial/types.html.

[47] "Educational Facilities." Type of Facilities. Accessed October 21, 2016. https://www3.epa.gov/watersense/commercial/types.html.

Figure 7: End Uses of Water in Schools[48]

Using less water means moving and treating less water which in turn helps to reduce the strain on water supplies and drinking water and wastewater infrastructure. Delivering water and wastewater services is energy intensive and reducing the strain on these facilities will in turn reduce energy usage. EPA estimates 3 to 4 percent of national electricity consumption, equivalent to approximately 56 billion kilowatts, or $4 billion, is used to provide drinking water and wastewater services each year.[49] Water and wastewater utilities are typically the largest consumers of energy that account for 30 to 40 percent of total energy consumed. Implementing energy efficiency measures at water sector systems can significantly reduce operating costs and mitigate the effects of climate change.[50]

3.2 Water Efficient Solutions

Water efficiency is the smart use of our water resources through water saving technologies as well as simple steps that can be taken in our daily lives. Using water efficiently will help to preserve water resources for the future generations.

Implementing water conservation in schools offers a twofold benefit. The first benefit being that the facility is saving water and the second being that the students are able to receive education and experience on water conservation topics. The high person/fixture ratio that occurs in schools leads to a high frequency in use that in turn leads to a fast payback on conservation investments. While there are many opportunities for cost

[48] "Educational Facilities." Type of Facilities. Accessed October 21, 2016. https://www3.epa.gov/watersense/commercial/types.html.
[49] "Water and Energy Efficiency." Sustainable Water. Accessed October 21, 2016. https://www.epa.gov/sustainable-water-infrastructure/water-and-energy-efficiency.
[50] "Water and Energy Efficiency." Sustainable Water. Accessed October 21, 2016. https://www.epa.gov/sustainable-water-infrastructure/water-and-energy-efficiency.

savings, implementation due to budgetary restrictions can become an obstacle. While looking at schools, it is important to consider durability, and tamper resistance wherever the students have access to the fixtures, equipment and appliances.

3.3 Water Efficient Appliances

3.3.1 Introduction

The average family spends $1,100 per year in water costs but can save $350 from retrofitting with WaterSense labeled fixtures and ENERGY STAR qualified appliances.[51] By reducing the amount of water that is used we can also begin to use less electricity.

3.3.2 Toilets

Restrooms are one of the main sources of water use in educational facilities accounting for 45% of educational facilities water use.[52] Older toilets are inefficient and use as much as 6 gallons per flush and are a major source of wasted water in restrooms.[53] The frequency of toilet flushes per toilet is greater in schools than many other facilities but is variable from school to school. It is reasonable to assume an average of 2 to 4 flushes per student per school day.[54] Nationally, if all old, inefficient toilets in the United States were replaced with WaterSense labeled models, we could save 520 billion gallons of water per year, or the amount of water that flows over Niagara Falls in about 12 days.[55]

The predominant type of toilet in schools is flush-o-meter toilets(tankless). Both the bowl and the flush valve must be replaced to assure water savings as well as adequate flushing performance. The cost to replace a flush-o-meter type of toilet usually ranges from $250-$400 depending on the type of toilet required.[56] Wall mounted toilets are usually the most expensive to replace and toilet models that are suitable for retrofit are limited. In addition, some schools provide child size toilets for younger students. These are usually gravity tank type and are expensive since there is a limited market.

Water savings can be achieved by replacing older model toilets that typically use 3.5 GPF (13.2 LPF) or greater with new ULFTs (1.6 GPF (6.1 LPF)) or dual flush toilets using 1.6 GPF for solid waste and 1.0 GPF for liquid waste. Low volume toilets, also

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[51] "WaterSense Labeled Products." WaterSense. 2016. Accessed October 21, 2016. https://www3.epa.gov/watersense/products/index.html.

[52] "Educational Facilities." Type of Facilities. Accessed October 21, 2016. https://www3.epa.gov/watersense/commercial/types.html.

[53] "WaterSense Labeled Products." WaterSense. 2016. Accessed October 21, 2016. https://www3.epa.gov/watersense/products/index.html.

[54] "Schools K - 12 Introduction." Accessed October 21, 2016. http://www.allianceforwaterefficiency.org/Schools_K_-_12.aspx.

[55] "WaterSense Labeled Products." WaterSense. 2016. Accessed October 21, 2016. https://www3.epa.gov/watersense/products/index.html.

[56] "Schools K - 12 Introduction." Accessed October 21, 2016. http://www.allianceforwaterefficiency.org/Schools_K_-_12.aspx.

referred to as low flow, low flush, low consumption ultra-low flush and ultra-low volume typically us 1.6 GPF or less.[57]

Low Volume Toilets

Gravity Tank Toilets

Figure 8: Gravity Tank Toilet[58]

The gravity tank or gravity flush toilet is the most commonly used toilet but is mostly used in homes. Gravity tank toilets account for 80% of toilets sold in the United States.[59] A gravity tank toilet operates when the handle is pulled, causing the flush(flapper) valve at the bottom of the toilet to open and start releasing water from the tank into the bowl. The weight of the water pressured by gravity causes the water to run out of the tank and into the bowl either through rim holes at the top of the bowl, a siphon hole, or both. This rushing of water creates a vacuum or siphon which pulls solid and liquid wastes from the bowl into the trap way (or outlet) and into the sewer drain below. As the bowl is being emptied, the flapper valve inside the tank closes to lie flat against the bottom of the tank and the ballcock, automatic fill valve, is tripped to allow water to empty and refill the tank. Gravity tank toilets usually require a minimum water pressure of 10 to 115 pounds per square inch (psi) to work properly.

Dual Flush Toilets

Dual flush toilets are designed with either one or two flush handles (levers). Flushes for liquid only wastes can be activated by depressing the handle in the direction

[57] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[58] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[59] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

for minimal flush (1.0 GPF or less), and flushes for solid wastes can be activated by depressing the handle in the opposite direction for a full flush (1.6 GPF or less).[60] If dual flush toilets are not flushed properly, for example flushing for liquid waste only when solids are present, dual flush toilets can clog or require double flushing. Signs or arrows should be posted near dual flush toilets to instruct people how to flush them correctly. In a school setting it is particularly important that students learn and understand how to flush the toilets correctly.

Low Volume Flushometer Tank (Pressurized) Toilets

The exterior of the flushometer tank toilets is usually identical to those of gravity tank toilets. The difference between the two types is on the inside of the flushometer tank, which contains a pressurized plastic vessel that holds the water used for flushing. When the flushometer tank toilet is flushed, compressed air forces the water out of the tank and into the bowl. This induces symphonic action that pushes the contents of the bowl down the drain. These types of toilets clear the bowl in less than 10 seconds but need 60 to 90 seconds to complete the flushing cycle and refill the plastic tank before it can be flushed again.[61] The flushometer tank is virtually leak proof because the pressurized vessel is inside of the tank. This is an important thing to consider when thinking about total water savings and life cycle costs of a fixture.

Low Volume Flushometer-Valve Toilets

Flushometer valve toilets are tank less fixtures that have a wall or floor mounted bowl and a flushometer bowl and a flushometer valve with a hand lever. This type of fixture is found on office, commercial and institutional settings, and high traffic facilities. Flushometer valve toilets operate on the same principles of flushometer tank toilets in that pressure from the water supply line creates a strong flushing action.[62]

Some flushometer toilets are operated with an infrared or fiber optic sensor that flushes the fixture automatically. The sensor is located on the wall behind the toilet which triggers the flushing mechanism once the user moves away from the fixture. These devices are usually used to prevent the spread of germs. Automatic sensor devices do not save water and can sometimes waste water because the sensor might be set incorrectly or be hyper sensitive and cause multiple flushing. To prevent unnecessary flushing, the sensor should have a time delay circuit.

Waterless Toilets

Waterless toilets that are typically used are composting or incinerator units that require no water for flushing. Oil flush, chemical and vacuum toilets are waterless alternatives that are less frequently used. Waterless toilets require no water for flushing and use a small amount of water for cleaning and maintenance.

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[60] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[61] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[62] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

Composting Toilets

Figure 9: Composting Toilet[63]

Composting toilets are not flushed and do not need water to convert human waste into humus and therefore require no connections to plumbing systems. Composting toilets rely on microorganisms that are naturally present in human waste and added bulk material to decompose, or compost, the waste.[64]

There are two types of composting toilets-self-contained units and central composting systems. Self-contained units are smaller and portable and some require electricity while others do not. Central composting toilets are larger and collect waste from one or multiple toilets and urinals that are connected to a collection and decomposition tank, or composter which is usually located in the basement or adjacent to a building. Centralized composting units are available in electric and non-electric models and there are solar powered systems that are available.

Composting toilets collect waste that fall from the toilet bowl into a compost tank that sits either directly under the toilet or are connected to it by a chute. There is no flushing with water, although chemicals may be used to move solid waste into the tank. Once the waste is inside the tank, the wastes are mixed with organic bulk material (wood shavings, mulches, sawdust, grass clippings, or leaves) and fresh air (oxygen). Waste is then mixed, either manually or automatically depending on the manufacturers design. Organic carbon in the mixing material and solid waste as well as nitrogen from the urine promotes the growth of aerobic (oxygen hungry) bacteria which facilitates the

[63] "Composting Toilet." Digital image. How Composting Toilets Work. Accessed December 3, 2016. http://www.tradewindsimports.com/images/how-compost-toilets-work.jpg.
[64] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

decomposition of wastes in the tank. This process creates carbon dioxide and water vapor which are then vented.

Adequate warmth (65 degrees F or higher) and air circulation are required to evaporate water from the waste and promote decomposition. To maintain aerobic conditions, the process needs adequate moisture, usually 40 to 75% within the composting pile. Temperatures below 50 degrees F will slow decomposition but won't stop it and waste breakdown usually resumes as the chamber is warmed. A small heater is usually installed in the tank for operation during winter or cold climates. The composting mixture should be mixed periodically to aerate and blend the composts and some systems have a motor and fan inside the composter for this purpose. The composting process reduces the original waste material by up to 90% after venting carbon dioxide and water vapor. The product should be odor free and safe if the process has been correctly managed.

Incinerator Toilets

Incinerator toilets use high temperature electric or propane heat to burn wastes. This leaves behind a fine ash byproduct. These types of toilets are usually used on boats and in remote locations where plumbing and composting toilets are not practical.

A basic incinerator toilet consists of a box like unit with a fan to control temperatures and to vent gases and moisture outside through a polyvinyl chloride or metal pipe.[65] Waste is deposited onto a plastic liner inside the unit and a button or switch is activated to begin the incineration process after each use. After waste is destroyed, a fan cools the toilet and vents the heated exhaust.

3.3.3 Urinals

Urinals can account for a major portion of indoor water usage in commercial and institutional settings. While the current federal standard for commercial urinals is 1.0 gallon per flush, some older units use as much as five times that amount.[66] Low volume urinals generally require 1.0 GPF or less and urinals that use 1.5 gpf are sometimes referred to as low volume. Moderate to high volume urinals have flush rates of 1.5, 2.0, 3.0, 4.5 and 5.0 gpf and continuous and intermittent flow urinals can use even higher volumes of water.[67]

Replacing inefficient fixtures with WaterSense labeled flushing urinals can save between 0.5 and 4.5 gallons per flush without sacrificing performance.[68] Replacing outdated models can result in water savings as well as cost savings by saving money on water bills. The benefit of replacing urinals depends on the frequency of use and the type

[65] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[66] "WaterSense Labeled Products." WaterSense. 2016. Accessed October 21, 2016. https://www3.epa.gov/watersense/products/index.html.
[67] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[68] "WaterSense Labeled Products." WaterSense. 2016. Accessed October 21, 2016. https://www3.epa.gov/watersense/products/index.html.

of proposed replacements.[69] Urinal replacements can range from replacing the flush valve to reduced flows, to replacing the entire urinal to a zero-water use model. Replacing just one inefficient urinal that uses 1.5 GPF with a WaterSense model could save a facility more than 4,600 gallons of water per year.[70]

Low volume flushometer valve urinals that use 1.0 gpf or less can be installed to replace high volume urinals often with no modifications to the bowl or to wall or floor connections. Low volume, flush valve urinals operate the same as high volume, flush valve urinals except that the diaphragm orifice in the valve has a smaller diameter.

Figure 10: Waterless Urinal[71]

Waterless urinals require no water for flushing and can often replace conventional fixtures that are connected to standard 2 inch drain lines.[72] Waterless urinals require different maintenance than flush urinals. Maintenance personnel need to be instructed on how to replace the trap seal when necessary and how to wash the fixture because flushing without water will leave more urine residue on the bowl.

Composting urinals require no water and are connected to composting toilet systems. Urine deposited in a composting urinal is conveyed by gravity through a vertical

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[69] "Schools K - 12 Introduction." Accessed October 21, 2016. http://www.allianceforwaterefficiency.org/Schools_K_-_12.aspx.

[70] "WaterSense Labeled Products." WaterSense. 2016. Accessed October 21, 2016. https://www3.epa.gov/watersense/products/index.html.

[71] "Waterless Urinal." Digital image. Http://media.treehugger.com/assets/images/2011/10/waterless-urinal-technology.jpg. Accessed December 3, 2016. http://media.treehugger.com/assets/images/2011/10/waterless-urinal-technology.jpg.

[72] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

drain directly to the composter.[73] A fan is used to vent the composter and creates a negative pressure that draws air from the urinal drain and prevents the escape of odor and gases through the fixture. Decomposition of urine waste occurs in the composter.

3.3.4 Showers

Many schools have showering facilities within the campus for PE classes and sports teams for the school. The Energy Policy Act of 1995 set maximum showerhead flow rates at 2.5 gallons per minute (GPM (9.5 LPM). Despite this mandate, some shower flows can still be found flowing in excess of 5 GPM (18.92 LPM).[74] In addition, many shower heads are easily altered to higher flow rates. Replacing excessive flow showerheads is one of the most cost effective retrofits inside of schools.

Low volume showerheads improve water efficiency through measures such as improved spray patterns, better mixing of air with water, and narrower spray areas to give the user the feel of water without high volume flows. Flow restrictors are sometimes embedded in low volume showerheads. Some flow restrictors are permanent while others can be removed for cleaning then reinstalled. Showerheads with flow restrictors are generally less expensive than those with a flow control device. A flow control device is a disk containing an elastic O-ring that is controlled by pressure. Under high water pressure the O-ring flattens and reduces water flow and under low pressure the O-ring relaxes and allows for a higher flow. This provides smoother changes in spray patterns when compared with flow restrictors.

3.3.5 Faucets

Flow rates for wash basin faucets can be reasonably reduced to 1.0 GPM (3.78 LPM) or lower.[75] Projected savings are usually based on usage frequencies that are similar to toilet and urinal use. Flow durations are estimated to average 5 to 30 seconds per use. Retrofitting aerators on the faucets is the most common strategy and is relatively inexpensive.

Most schools wash basins have mechanical metering valves or negative shut off valves. Mechanical metering valves automatically shut off after a preset time space and negative shut off valves require the use to exert pressure on the valve handle to maintain water flow. Both types of valves are required to deter vandalism of students purposefully flooding the lavatories. These valves are often adjustable for the duration of the flow and should not exceed 5 seconds per activation.

Low volume faucets generally look the same as high volume fixtures. Reduced flows for low flow faucets can be achieved with aeration or flow control devices, spray features or a combination of these options. Aerators or flow control devices are usually

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[73] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[74] "Schools K - 12 Introduction." Accessed October 21, 2016. http://www.allianceforwaterefficiency.org/Schools_K_-_12.aspx.
[75] "Schools K - 12 Introduction." Accessed October 21, 2016. http://www.allianceforwaterefficiency.org/Schools_K_-_12.aspx.

located at the end of the faucet or are incorporated into the tee that connects the hot and cold services at the base of the faucet. Some faucets have an embedded flow restrictor that is located at the tee of the faucet. The restrictor may be a narrowed opening or an elastic O-ring that restricts flow based on water pressure. Other faucets have laminar flow attachments that create many thin parallel streams of water which produces a clear flow that is not mixed with air.

3.3.6 Food Preparation

There are many opportunities to conserve water in the flood preparation and dishwashing areas since many schools serve lunch to students. Food is often heated in steamers using a central boiler. Connectionless steamers are an alternative that save thousands of gallons of water per year. Pre-rinse spray valves that are used to rinse dishes before they are placed in the dishwasher use about 4 GPM (15.1 LPM). New and efficient spray valves use only 1.6 GPM (6.1 LPM) and can save hundreds of gallons a day depending on how many meals are served.[76]

3.4 Cooling Water Systems

Cooling systems generate a large amount of heat that must be dissipated continually. Flowing water is a medium that is frequently used to remove heat which can be dissipated through evaporation. Water is used most often for cooling since it is readily available, cheap, has an ability to absorb large amounts of heat per square area and can be discharged to the sewers, creek or sea.[77] Water that is used for cooling represents a large amount of water use in water demand in the United States. Cooling water is used to take away heat that is generated by building and process cooling systems, air and vacuum pumps, compressors, large commercial freezers and refrigerators and ice machines. There are four common types of cooling systems that involve the use of water: these are once-through (or single pass) cooling, cooling towers, evaporative coolers and equipment cooling.[78]

Some schools use a cooling tower in the HVAC system to cool the building. Depending on the climate zone and the cooling system, the water wasted can be more than all the sanitary fixtures combined. Appropriate retrofits usually require a conductivity controller to be installed and properly maintained to achieve water efficiency.

3.4.1 Once-Through (Single Pass) Cooling Systems

Once pass through cooling systems are the most water intensive cooling method. These systems are inefficient because water is channeled through a piece of equipment or cooling system once and then discarded, usually into the sewer drain.[79] This can waste

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[76] "Schools K - 12 Introduction." Accessed October 21, 2016. http://www.allianceforwaterefficiency.org/Schools_K_-_12.aspx.
[77] Seneviratne, Mohan. Water Conservation for Commercial and Industrial Facilities. Burlington, MA: Elsevier, 2007.
[78] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[79] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

water, energy, as well as money. These can be found in air conditioners and air conditioning systems, equipment cooling systems, refrigeration systems, condensers, air compressors, process tanks, ice machines, and hydraulic presses and equipment.

There are water efficiency measures that can be applied to once through cooling systems to save water. One measure is to eliminate these systems. Unless water from single pass-through processes are reused for another purpose, these systems should be eliminated since they are inefficient. Facilities that use a significant amount of water for once through cooling systems can often achieve short paybacks on investment in more water efficient cooling systems.[80] Water cooled equipment such as compressors, vacuum pumps, and ice machines should be replaced with air cooled and energy efficient models. This will help to save water as well as energy. Some once through systems can also be retrofitted so that they are a close looped system that recycles the water. Retrofitting the system would include adding a pipe that returns the discharge water back into the system inlet. Automatic controls can also be used to operate single pass through cooling units so that they are only being used when it is needed, such as during operation hours. An automated shut off valve can be installed to stop single pass flows to compressor intercoolers and air dryers when the compressor is not running.[81] This strategy can also be used on water cooled equipment. Another option can be to use a temperature controlled valve which adjusts the flow of water to maintain a certain temperature. This means that only the volume of water that meets the required temperature is used.

Exit temperatures should be monitored as water leaves each piece of cooling equipment. If water leaving identical pieces of equipment differs, this should be investigated. This may be due to equipment receiving higher volumes of flow than needed. If this is happening, the appropriate exit temperatures should be determined and the water circulation rate should be adjusted accordingly.

Water from single pass through water systems can also be reused for other purposes. Water from these systems can be diverted to other equipment with water cooled units, landscape irrigation, vehicle washing, and maintenance purposes.

3.4.2 Cooling Towers

Cooling towers use significant amounts of water to operate air conditioning, process cooling and refrigeration systems in the industrial, commercial and institutional sector. Cooling towers however use 90-95% less water than once through systems since they use the water repeatedly.[82] Although they use less water than once through systems, cooling towers are often the largest single user of water in industrial plants, large office buildings, hospitals, hotels, schools and other facilities with large air conditioning or cooling requirements.

[80] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[81] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[82] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

Evaporation

Cooling towers use evaporation to lower the temperature of water that has been heated through the operation of a building process or piece of equipment such as an air conditioning system. As the temperature of the air within a building is lowered by a water cooled air-conditioning system, the cooling water becomes warmer and heat exchange occurs. The water from a cooling tower is returned to the tower for re-cooling and the cycle is then repeated.[83] Water is re-cooled by exposing the stream of warm water to a flow of air in the tower which causes the water to evaporate. As the warmed water evaporates, heat escapes and the remaining water is cooled.

The capacity of a cooling tower is expressed in terms of tons. One ton of cooling equals 12,000 British thermal units (Btus) per hour. The capacities of cooling towers typically range from 50 to 1,000 tons or more and large facilities may be equipped with several cooling towers. The number of cooling towers in operation in the United States has been estimated at more than 350,000; about 50% of these are sized at 300 tons or smaller.[84]

Cooling towers typically lose water through evaporation, bleed off, drift and other losses. These losses are replaced with make-up water. Cooling towers operate by causing a portion of the warmed water to change from a liquid state to vapor, a process that cools the water left behind; this results in evaporation. The amount of evaporation that occurs depends on the length of time that the cooling water remains in contact with the air, the temperature of the air and water and the wind.[85] Evaporation accounts for 1 to 3% loss of circulating water from cooling towers.[86]Evaporation in a cooling tower typically occurs at a rate of about 1% of the rate of recirculating water flow for every 10 degrees F temperature drop.[87] This varies on the amount of cooling achieved and weather conditions.

Bleed-off (blowdown)

Blowdown water is a process that preserves the life and efficiency of equipment as it reduces the buildup of solids (salts, dirt, calcium, rust) in the system. Because water that evaporates from a cooling tower is pure vapor, dissolved and suspended solids that are normally present in the water are left behind in the cooling tower, where they become concentrated in the recirculating water. “Bleed-off” or “blowdown” involves releasing a small portion of the circulating water that contains high concentration of the total dissolved solids (TDS) and replacing it with fresh make-up water.[88] Without bleed off, concentration of TDS can build up and cause damage to the cooling tower and process through scale buildup, corrosion and biological growth. Water from bleed off is then

[83] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[84] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[85] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[86] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[87] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[88] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

drained into a sanitary sewer or storm drain. Blowdown is usually regulated and controlled by automatic devices that release bleed off when the conductivity of the water reaches a preset value (high TDS). To lower the conductivity of the water, the “batch method” is often used in which large volumes of water are discharged until a predetermined low value is reached.

One way to evaluate cooling tower operation is “cycle of concentration”. This is determined by calculating the ratio of concentration of dissolved solids in the blowdown water compared to the make-up water. Since dissolved solids enter the systems in the makeup water and exit the system in the blowdown water the cycles of concentration are approximately equal to the relation of volume of make up to blow down water.[89] Maximizing the cycle of concentration is most efficient in terms of water use. This reduces the amount of blowdown and reduces the amount of make-up water that is needed within the system. Many systems operate at two to four cycles of concentration, while six cycles or more may be possible. Increasing cycles from three to six reduces cooling tower make-up water by 20% and cooling tower blowdown by 50%.[90]

Figure 11: Percent of Make-Up Water Saved by Maximizing Cycles of Concentration[91]

In addition to controlling blowdown, another way to reduce water use is to use other sources of makeup water. Water from other facility equipment can sometimes be recycled and reused for cooling tower makeup with little or no pretreatment including: air handler condensate (water that collects when warm, moist air passes over the cooling

[89] "Best Management Practice #10: Cooling Tower Management." Best Management Practice #10: Cooling Tower Management | Department of Energy. Accessed December 08, 2016. http://energy.gov/eere/femp/best-management-practice-10-cooling-tower-management.

[90] "Best Management Practice #10: Cooling Tower Management." Best Management Practice #10: Cooling Tower Management | Department of Energy. Accessed December 08, 2016. http://energy.gov/eere/femp/best-management-practice-10-cooling-tower-management.

[91] Water Sense at Work: Best Management Practices for Commercial and Institutional Facilities. EPA, 2012.

coils in air handler units), water used in once through cooling systems, pretreated effluent from other processes provided chemicals used are compatible with cooling tower system, high quality municipal wastewater effluent or recycled water.[92] Using makeup water that consists of at least 50% non-potable water, such as harvested rainwater, harvested storm water, air-conditioner condensate, swimming pool filter backwash water, cooling tower blowdown, pass-through (once-through) cooling water, recycled treated wastewater from toilet and urinal flushing, foundation drain water, municipally reclaimed water or any other appropriate on-site water source that is not naturally occurring groundwater or surface water can earn users LEED credits for non-potable water source use in cooling tower management.[93]

Another way to save water is to install a conductivity controller to automatically control blowdown. A conductivity controller can measure the conductivity of the cooling tower water and discharge water only when the conductivity set point is exceeded. This increases the cycle of concentration and reduces water use. [94]

Water use can also be reduced by reusing blowdown water. Blowdown water is typically higher in dissolved solids but can be used for wash down, cleaning and toilet flushing.[95]

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[92] "Best Management Practice #10: Cooling Tower Management." Best Management Practice #10: Cooling Tower Management | Department of Energy. Accessed December 08, 2016. http://energy.gov/eere/femp/best-management-practice-10-cooling-tower-management.

[93] "Cooling Tower Water Management | U.S. Green Building Council." U.S. Green Building Council. Accessed December 08, 2016. http://www.usgbc.org/credits/we5.

[94] "Best Management Practice #10: Cooling Tower Management." Best Management Practice #10: Cooling Tower Management | Department of Energy. Accessed December 08, 2016. http://energy.gov/eere/femp/best-management-practice-10-cooling-tower-management.

[95] "Best Management Practice #10: Cooling Tower Management." Best Management Practice #10: Cooling Tower Management | Department of Energy. Accessed December 08, 2016. http://energy.gov/eere/femp/best-management-practice-10-cooling-tower-management.

Drift and other losses

Figure 12: Cooling Tower System[96]

Drift is droplets of cooling tower water are also carried away by airflow in the form of mist. Drift contains suspended and dissolved solids and can be considered part of the cooling tower's bleed off. Drift rates vary depending on the type of cooling tower. These rates are relatively low and range between 0.05 and 0.2% of the airflow rate.[97] In addition to drift, other types of losses include valve leaks and drawn down or draw off for miscellaneous uses. Design features such as drift eliminators or internal walls will reduce water loss in open loop cooling towers.[98] The sum of water that is lost from the tower must be replaced by makeup water:[99]

$$\text{Make-up} = \text{evaporation} + \text{blowdown} + \text{drift}$$

[96] Water Sense at Work: Best Management Practices for Commercial and Institutional Facilities. EPA, 2012.

[97] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

[98] "Best Management Practice #10: Cooling Tower Management." Best Management Practice #10: Cooling Tower Management | Department of Energy. Accessed December 08, 2016. http://energy.gov/eere/femp/best-management-practice-10-cooling-tower-management.

[99] "Best Management Practice #10: Cooling Tower Management." Best Management Practice #10: Cooling Tower Management | Department of Energy. Accessed December 08, 2016. http://energy.gov/eere/femp/best-management-practice-10-cooling-tower-management.

3.5 Measuring Systems

To achieve water efficiency, it is essential to measure how much water is being used. Meters are used to measure flow rates and consumption. Meters can provide information about how much and where water is being used. This helps to monitor water use and identifying waste as well as pinpointing opportunities to save water during specific types of water use. Meters should be accurate, correctly sized, and read on a regular basis. There are three main categories of meters-main meters, sub meters and flow meters.

Main meter

The main meter measures total water inflows to the facility. If the facility has a number of buildings, the utility often installs several meters. The customer's water and sewage bill will usually show the readings that were recorded for each meter during a billing period.

The main meter can provide an understanding of baseline water demand as well as patterns of use if the meter is read on a frequent *daily, weekly, monthly) basis. Customers that regularly check the main meter can help verify the accuracy of the meter and water and sewer bills. Regular reports of water use data keep users informed of water savings and progress in achieving water efficiency and conservation goals.

Sub meters

Installing sub meters in facilities can have many benefits. Sub meters can be used to monitor specific water uses such as those for cooling towers, irrigation and other significant sources of demand. Sub meters can provide information on water uses and costs for specific processes so users can assess how they can increase efficiency and conservation in specific areas. This will also help users to understand where water is being used within the building and asses where the most cost savings can occur. If water use is higher than expected in some areas, the user can use this information to track down the sources for potential inefficiencies within the system.

Sub meters can also be used to compare the amount of water used with sewer discharges. This can be used to reduce sewage costs. Many water utilities base sewage bills on the amount of water metered, even though water lost through evaporation or used for irrigation and other consumptive uses is never discharged into the sewer system. If a facility loses or consumes significant amounts of water through evaporation or other processes it can use measurements of such "lost" water to support the case for a sewage adjustment bill.

Flow meters and temporary metering devices

A number of flow meters, totalizers and similar types of portable measurement devices can be used permanently or temporarily to measure flow rates or volume uses for a specific site, piece of equipment or process.

The main meters and sub meters that are used to measure water use are usually cumulative meters. The three types of cumulative meters that are commonly used are positive displacement meters, turbine meters and compound meters.

Positive displacement (PD) also known as volumetric refers to the movement of the meter's flow sensing element which displaces a specific volume for each cycle.[100] Positive displacement meters contain an oscillating piston or rotating device that moves water in a rotary motion and the meters translate measurement of volume into flow.[101] The flow rate is calculated based on the number of times the compartments are filled and emptied and are then multiplied by a constant that is established for volume per cycle.[102] Positive displacement meters are often used in residential and small commercial projects since they provide extremely accurate readings when measuring low volumes of water. PD meters are not designed to operate continuously at high flows for long periods of time as they can become damaged and give inaccurate readings under such conditions. Positive displacement meters cannot be calibrated. Any undue clearances (due to wear and tear or from impure water sources) between the rotating elements and the outer chamber in which it rotates allow water to pass through without being registered.[103] Since these types of meters cannot be calibrated it is important to make sure that these types of meters are working properly and giving accurate readings.

Velocity meters operate on the principle that water passing through a known cross sectional area with a measured velocity can be equated into a known volume of flow as per the equation ($Q=V \times A$).[104] In the equation, Q is liquid flow through the pipe, V is the average velocity of flow, and A is the cross-sectional area of the pipe. Turbine meters are a common type of velocity meters that contains a multi-vaned rotor that spins as water flows through the meter; they register flow proportionally to the spin of the rotor.[105] These meters are best if used to measure large flow volumes such as those for irrigation and large volume industrial and commercial applications. Turbine meters can also give accurate flow readings for medium volume flows. If a turbine rotor's blades become coated or clogged with sediment it can under register flows.

Compound meters consist of two meters in one. They are used in facilities that have high and low volume flows. An industrial building that has high volumes of flow during the day but low volumes at night might be measured most accurately with compound meters. There is usually a large and small diameter component to a compound

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[100] Seneviratne, Mohan. Water Conservation for Commercial and Industrial Facilities. Burlington, MA: Elsevier, 2007.
[101] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[102] Seneviratne, Mohan. Water Conservation for Commercial and Industrial Facilities. Burlington, MA: Elsevier, 2007.
[103] Seneviratne, Mohan. Water Conservation for Commercial and Industrial Facilities. Burlington, MA: Elsevier, 2007.
[104] Seneviratne, Mohan. Water Conservation for Commercial and Industrial Facilities. Burlington, MA: Elsevier, 2007.
[105] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

meter. The larger diameter component is a turbine meter and the smaller component is a displacement meter. The smaller meter measures low flows and when the flow rates increase, the larger meter measures them. Compound meters' record total meters' volume either on a single register (dial) or on a separate register for each meter, for which reading both registers is required to determine total use.

Meters are often sized to match the diameter of the water service line that supplies the customer but this may not always result in accurate readings of water use because actual flows tend to be lower than the maximum flow pipes are designed to handle. Having a meter sizing analysis is recommended as part of an on-site water use efficiency evaluation. Proper meter sizing is dependent upon the types of lows and water demands at the facility. It should also consider daily and seasonal flows.

Sub meters should be used to optimize water use and lower water costs. Sub meters should be read frequently if they are to yield beneficial information to the users. Meters can provide indirect savings since they provide information that can be used to assess water use and identify opportunities to reduce unnecessary water demand, leaks and loses.[106]

3.6 Conclusion

Incorporating water efficient solutions and appliances is a good start to beginning to use less water. By using less water, users can save money. When water is used more efficiently, the need for costly investments in water treatment and delivery systems is reduced. In addition, the amount of water that needs to be transported is reduced thus reducing costs for the user. Using water more efficiently will help to conserve and ensure that there are reliable water supplies for future generations.

[106] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

4. Water Conservation

4.1 Introduction

In 1990, 30 states in the US reported 'water-stress' conditions. In 2000, the number of states reporting water-stress rose to 40. In 2009, the number rose to 45.[107] The trend of a stressed water supply is worsening around the world. Taking measures to conserve water can save money and benefit the community.

Since our water resources in Hawaii are so limited it is important for us to conserve water so that we will have enough for the years to come. Water conservation can be defined as policies, strategies and activities that are made to manage water as a sustainable resource.[108] This includes protecting and preserving water resources to meet the demands of the current population and future generations. Making small changes in our daily patterns can result in huge changes in the amount of water that we use a day. This section explores different ways to save water.

4.2 Water Conservation Strategies

4.2.1 Indoors

Buildings should be monitored for leaks in plumbing or toilets. Users can check for leaks by turning off the water, checking the water meter, then checking back two hours later. If the meter has moved, something is leaking. A small drip from a worn faucet can waste 20 gallons of water per day.[109] Larger leaks can waste hundreds of gallons. Checking pipes and faucets for leaks can help to conserve the amount of water used.

Install water efficient plumbing fixtures. Water efficient toilets can save at least five gallons every flush and shower heads can save up to five gallons every minute.[110]

Taking shorter showers is another way that we can begin to conserve water. Every minute that you shower, you are using three to six gallons of water.[111] Getting in and out of the shower a little faster can reduce the amount of water that you are using. Pausing the water while you shampoo, lather or shave is another great way to begin to conserve water.

Not letting the faucet run is another small step that can be taken to conserve water. By turning off the tap when brushing your teeth or shaving you can reduce the amount of water that is used.

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[107] "Eartheasy." Water Conservation: 25 Ways to Conserve Water in the Home and Yard. Accessed November 04, 2016. http://eartheasy.com/live_water_saving.htm.

[108] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

[109] "Eartheasy." Water Conservation: 25 Ways to Conserve Water in the Home and Yard. Accessed November 04, 2016. http://eartheasy.com/live_water_saving.htm.

[110] "Conservation." Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation.

[111] "Conservation." Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation.

4.2.2 Outdoors

Design and irrigation practices of landscaped areas in the United States usually do not use water efficiently and no longer represent the native environment. Landscaping can have its costs and benefits but must be managed properly. Excessive irrigation can result in increased water costs, deplete water supply sources and other natural systems, add to pollution from lawn and other landscape chemicals and requires time, labor and energy for maintenance. On the other hand, irrigated landscapes support important functional, recreations, aesthetic and economic interests for society, including erosion control, temperature modification, and the creation of recreational areas such as playing fields, parks and golf courses.[112] These areas enhance the functional and aesthetic value of land as well as expanding the economic value of residential and commercial real estate around which communities are sustained.

Landscape irrigation uses 50 percent or more of household drinking water. Irrigation systems that are poorly maintained or installed can waste up to 50 percent of water due to inefficient irrigation practices, poor components, evaporation and runoff.[113] Maintaining and installing water efficient irrigation systems is one of the most effective ways to reduce wasted drinking water, reduce runoff, sediments and optimize plant health by applying the right amount of water.

Figure 13: Typical Seasonal Irrigation Schedule for Hawaii[114]

Poor irrigation scheduling such as watering too often and for too long is the primary source of water waste associated with landscape irrigation. Lawns should be only watered

[112] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[113] "Conservation." Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation.
[114] "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

2-3 times a week.[115] Even during summer, lawns do not need to be watered every day. If you water once every three days you promote deeper root growth which makes your lawns healthier and more water efficient.[116] In addition, lawns should not be watered between 9am and 5pm as water evaporates quickly when the sun is out. Watering in the early morning or evening will keep the water from evaporating and keep the water in your lawn. Watering once or twice a week for 15 to 30 minutes is adequate for most landscapes.[117] Plants that have become accustomed to being water logged may need to transition to receiving less water slowly to avoid shock. Once plants have become accustomed to receiving less water and have deeper roots they should be able to flourish with less water. Users should also adjust their irrigation schedule throughout the year in response to soil conditions and seasonal weather conditions. Run times should be adjusted at a minimum of four times a year: summer (dry season), winter (rainy season), and transition periods (fall and spring). Most controllers have built in functions for "seasonal adjust" or "water budget" to adjust for seasonal weather but if you are unsure you can decrease run time until plants are slightly stressed then slightly increase runtime. Adjusting schedules saves upwards of 40% of outdoor water usage.[118]

Putting a nozzle on the hose can reduce the amount of water used when water plants. A running garden hose that is left unattended can waste over 100 gallons in just minutes.[119] Using a nozzle that has a shutoff so that you are only using it when you are watering things can save gallons of water that would otherwise be wasted.

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115 "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

116 "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

117 Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

118 "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

119 "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

Figure 14: Typical Precipitation Rate Ranges[120]

Using water saving irrigation components such as rotary nozzles, pressure regulated spray heads/valves, rain switches or high efficiency nozzles can help to reduce the amount of water wasted when irrigating. Water can also be conserved by using climate based irrigation controllers (Smart Controllers) to schedule water based on weather conditions. Some products use real time or historic weather data to schedule irrigation based on evapotranspiration (ET). Evapotranspiration is the quantity of moisture that is both evaporated (E) from the soil and plant surface and transpired (T) by the plant.[121] Evapotranspiration is determined by weather conditions and plant type. This ensures that water will not be wasted and plants that have already received a sufficient amount of rainfall will not need to be watered. ET systems measure the local evapotranspiration (ET) factor using onsite sensors or satellites that monitor weather conditions such as rainfall, temperature, wind speed and soil moisture to constantly adjust run time and days

[120] "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

[121] "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

to water. The information is then downloaded to the host controller that creates an intelligent irrigation schedule that is right for the local landscape. This can result in as much as 30% reduction in water use.

Figure 15: Diagram of Head to Head Coverage[122]

Irrigation systems should be designed with sprinklers spaced with head to head coverage or better. Head to head coverage means that the throw from one sprinkler overlaps the neighboring sprinkler to prevent dry spots and over watering. Irrigation systems should also be programmed to encourage deep watering by using longer and less frequent watering times. This improves deep rooting and increases drought resistance. Short daily watering should be avoided, except for sandy soils.

[122] "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

Figure 16: Irrigation Precipitation, Runoff and Infiltration Rates[123]

Plants should be irrigated with a precipitation rate that does not exceed the soil infiltration rate. Precipitation rate is the speed at which an irrigation system applies water over a given area. Precipitation rate is measured in inches per hour where one inch per hour is equivalent to 620 gallons per 1,000 square feet.[124] The type of sprinkler heads used, their spacing and flow rate from each head can affect an irrigation system's precipitation rate.

Infiltration rate is the rate at which water moves into and down the soil.[125] Different types of soils have different infiltration rates. For example, clay soils absorb water slowly, loam soils have average absorption rates and sandy soils absorb water rapidly. Most of the soils in Hawaii are clay soils.

When the precipitation rate (rate at which water is being applied) is greater than the infiltration rate (ability of the soil to absorb water), water is wasted as runoff or by accumulating at the soil surface (ponding), and evaporating rather than being available to the plants. Irrigation run times should be reduced if ponding occurs.

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[123] "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

[124] "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

[125] "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

On large sites, an irrigation sub meter should be used. This will measure water consumption and provide useful water consumption information. Recording water use is part of the monthly inspection report. Installing an irrigation sub meter may save on sewer charges because you can use the amount of water used for irrigation to the sewer deduction versus the standard deduction.

Sprinklers that are in low lying areas and slopes should have check valves. This helps to prevent water from ponding and draining out at the lowest sprinkler head when the run time has ended.

Existing native trees and non-invasive vegetation should be preserved during development where feasible. Native vegetation has the best chance of surviving in landscapes that rely on natural rainfall only since it is naturally adapted to survive the temperature and weather extremes of its place of origin. Irrigation in these areas should not be installed.

Incorporate compost into soils at planting. Compost is decomposed organic matter (material derived from plants and animals) that can be used as a fertilizer or soil amendment.[126] Use of compost conserves water by improving water absorption and the water holding capacity of the soil. When added to sandy soils, compost acts as a sponge to help retain water that would otherwise drain down below the reach of plant roots. When added to clay soils, compost makes the soil more porous, making it drain more efficiently. Using compost also reduces green waste going into our landfills.

Garden beds should also be mulched to increase water filtration, reduce water pooling, and to minimize water loss due to evaporation. In addition, drip irrigation should be used to water shrubs, trees and plant beds to decrease water waste.

Grass should be allowed to grow taller in summer months to conserve water and encourage deep rooting. The same moving schedule should be used but use a higher mowing height. Mowing heights should remain within the recommended mowing height for each species of grass.

Lawns should be aerated when compaction occurs. Aeration involves perforating the soil with small holes to allow air, water and nutrients to penetrate the grass roots.[127] This helps the roots to grow deeper and produce a stronger lawn. Aerating alleviates soil compaction which prevents circulation within the soil. If possible, top-dress with a thin layer of compost or sand. Topdressing refers to the practice of applying a thin layer of compost to the surface of a lawn. This increases the soil's organic content, enhances

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[126] "7 Ways to Save Water." Conservation. Accessed October 21, 2016. http://www.boardofwatersupply.com/conservation/7-ways-to-save-water.

[127] "Aeration: Why, How & When to Aerate Your Lawn | Briggs & Stratton Lawn Care." Briggs & Stratton Lawn Care. Accessed December 07, 2016. https://www.briggsandstratton.com/na/en_us/support/maintenance-how-to/browse/aeration-why-how-and-when-to-aerate-your-lawn.html.

earthworm activity and serves as a mulch to protect the grasses shallow roots. Dethatch or verticut heavily thatching grass. Dethatching allows for deeper roots.

Xeriscape

Xeriscape is a term that is derived from the Greek word “xeros” (dry) and “scape” from landscape.[128] Xeriscape is a water management tool that conserves water through the landscape. An estimated 50 percent of water consumption in the average single family home is used outdoors.[129] Xeriscaping is a way to minimize water while still being able to maintain a beautiful outdoor landscape. Using principles of xeriscaping, water use can be reduced by 30-80%.[130]

Xeriscaping is based on seven principles that serve as guidelines on how to plan, plant and maintain a garden that takes advantage of natural climate conditions and makes efficient use of irrigation. The principles promote conserving water and protecting the environment. These principles include proper planning and design, soil analysis, appropriate plant selection, practical turn areas, efficient irrigation, use of mulches, and appropriate maintenance. [131]

A good xeriscape garden starts with good planning and design. Planning allows you to install your landscape in phases and can minimize expenses in the initial phases. When creating a master landscape plan there are a few design issues that should be addressed. These include:[132]

- Functional turf areas: Water savings can be achieved by reducing the amount of turf areas. The amount of turf that is needed for activities such as walking, sitting, and other recreational activities should be clearly defined. Nonfunctional areas can be covered with drought tolerant plants such as drought tolerant turf grass or alternative ground covers that are aesthetically pleasing.
- Nonfunctional plant and hardscape areas: Landscape areas that do not have a functional purpose can be filled with native and adaptive plants, trees and shrubs. Various hardscapes such as patios, decks, gravel areas and rock gardens can also be used. Non-permeable surfaces such as concrete or pavement should be avoided since they contribute to runoff. Permeable materials such as gravel and other porous paving materials should be utilized as they can help to prevent water from accumulating on walkways, driveways and parking areas.
- Landscape form: The form of the landscape can influence water efficiency. For example, irregular designs, narrow strips and small areas may be difficult to irrigate efficiently with automatic systems that deliver water in rectangular spray

[128] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[129] "Xeriscape." Board of Water Supply. Accessed October 30, 2016. http://www.boardofwatersupply.com/conservation/xeriscape.
[130] "Xeriscape." Board of Water Supply. Accessed October 30, 2016. http://www.boardofwatersupply.com/conservation/xeriscape.
[131] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[132] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.

patterns. This can result in overspray to nearby walkways and roads. These design elements may be more suited to be water with drip, watering can or hand held hose irrigation.

- Grading and drainage: Landscape grading and drainage can also affect a site's water efficiency. The type of soil as well as the slope affect soil water infiltration and runoff rates. Plants that have high volume water requirements should be placed in shallow basins to boost detention of rainwater or irrigation water. In areas that will not receive much water, little to no grading may be preferable. Minimizing irrigated slopes will help to reduce runoff and preserve topsoil. Since turf grass requires extensive irrigation, it is not ideal for steep grades as it will be difficult to irrigate uniformly, require more time to mow and are more prone to brown spots during hot, dry periods.
- Sun and shade: Areas that receive sun and shade during particular times of the day should be noted. Areas that receive hot, afternoon sun will require different plants than areas that are shaded for the duration the day. Shaded areas can be up to 20 degrees cooler than sunny areas.
- Water use zones: Vegetation can usually be divided into three water use zones: low (fed solely by rainfall), moderate (needs occasional watering), and high (requires regular watering). Low water use zones rely on natural rainfall and do not need supplemental irrigation. Moderate water use zones generally require watering only during hot dry periods. High water use zones include plants that would need regular watering. A water efficient landscape would include mainly low water use plants.
- Topsoil preservation: good quality topsoil should be preserved as it has better growing and moisture holding capacity than subsoil. Topsoil can be saved and stored and then returned to the landscape after the site has been regraded. Soil that is damaged or deficient in nutrients may need amendments.

Figure 17: Drought Tolerances of Common Turf Grasses[133]

Another principal in xeriscaping is limiting and separating turf areas. Since grassed areas need a great amount of watering, turf that is separated from trees, shrubs, ground cover and flower plants can be irrigated separately. Replacing turf with less water demanding plants such as ground covers or low water demanding plants or mulches can reduce the amount of water needed for irrigation. If a mowed, turf area is needed, some traditional turf may be necessary. Turf grass should be selected based on local rainfall ranges and the grass' ability to survive in drought or low water conditions. A grass that typically requires more water can be trained to require less water by encouraging deep root growth. Turf grass will initially need some irrigation to establish it in the ground. Aerating and amending the soil can improve a lawn's ability to retain moisture which will help to reduce excessive irrigation and runoff.

Systems should be designed to irrigate similar hydro zones. Hydro zones are sections of the landscape that have similar slope, sun exposure, soil conditions and plant materials with similar water use on the same watering zone circuit.[134] Planning and grouping plants together that have similar water needs can help to ensure that water is used efficiently. Turf areas are best watered with sprinklers and other areas such as trees, shrubs, garden flowers and ground covers can be watered with low volume drip, spray or bubble emitters. Moisture sensors that shut down the irrigation system when the ground is wet or on a rainy day also help to make sure that water is not wasted.

Soil improvement allows for better absorption of water and improved water holding capacity. Coupled with grading, soils and soil amendments that have organic matter which will provide nutrients to the plants will encourage whatever is planted to take root and flourish.[135] Soil amendments can also reduce compaction, aerating the soil

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[133] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[134] "Xeriscape." Board of Water Supply. Accessed October 30, 2016. http://www.boardofwatersupply.com/conservation/xeriscape.
[135] "Xeriscape." Board of Water Supply. Accessed October 30, 2016. http://www.boardofwatersupply.com/conservation/xeriscape.

to allow water and nutrients to more easily move through and reach plant roots.[136] Grading and soil improvements however should be done before the installation of irrigation systems.

Mulched planting beds can be an ideal replacement for turf areas as mulches cover and cool soil as well as minimizing evaporation, reducing weed growth and slowing erosion.[137] Organic mulches can consist of bark chips, wood grindings or bagasse. Inorganic mulches include rock and gravel products. Mulch can be placed directly on the soil or on a breathable fabric. Sheet plastic in planted areas should be avoided.

Plants that need less water can improve your garden by requiring less watering than others. Native plants that thrive on natural rainfall do best in a xeriscape. There are a number of popular flowering trees, shrubs and vines, and turf grasses which require less watering than others. There are also many native Hawaiian plants that need less water.

Xeriscapes can help to reduce maintenance costs of a landscape.[138] Pruning, weeding, proper fertilization, pest control and irrigation system adjustments further water savings and preserves the beauty of your landscape.

4.3 Conclusion

Since our water resources in Hawaii are so limited it is important for us to conserve water so that we will have enough for the years to come. Water conservation is important even in areas that have an abundance of water as we must preserve and ensure resources for the coming generations. The water conservation strategies can help to reduce the amount of water used by making small changes to everyday behavior. Much of the strategies are outdoor conservation strategies that can easily be applied to schools. Since schools have an abundance of outdoor spaces, many for recreational activities, it is important to use those spaces efficiently so that water is not being wasted in these areas. Making small changes in our daily patterns can result in huge changes in the amount of water that we use a day.

[136] "Soil and Soil Amendments Guide." Soil and Soil Amendments Guide. Accessed January 15, 2017. https://www.lowes.com/projects/gardening-and-outdoor/soil-and-soil-amendments-guide/article.
[137] Vickers, Amy. Handbook of Water Use and Conservation. Amherst, MA: Waterplow Press, 2001.
[138] "Xeriscape." Board of Water Supply. Accessed October 30, 2016. http://www.boardofwatersupply.com/conservation/xeriscape.

5. Water Reuse

5.1 Introduction

The growing population as well as the limited amount of potable water resources is reducing the availability as well as the quality of our drinking water supply.[139] Practices that protect, conserve and utilize water resources are vital to Hawaii. There are many water sources that are available on building sites that can supplement the more traditional water sources.[140] These water sources are non-potable and vary in quality. Water reuse or recycling is reusing treated wastewater for beneficial purposes such as agricultural or landscape irrigation, toilet flushing or replenishing a groundwater basin.[141] Wastewater treatment can be altered and configured to meet the water quality requirement of the planned reuse. Recycled water that will be used for landscape irrigation will need less treatment than water that is recycled for drinking water.

Another type of recycled water is “greywater”. Greywater is reusable wastewater from residential, commercial and industrial bathroom sinks, bath tub shower drains, and clothes washing equipment drains.[142] Greywater can be used on site and is typically used for landscape irrigation.

Water can be recycled and used on site. Using recycled water helps to reduce the amount of potable water that is needed at sites. This means that water reuse is saving water, energy, and money. A common type of recycled water is water that has been reclaimed from municipal wastewater or sewage. Recycled water can satisfy most water demands if it is treated to ensure water quality that is appropriate for the designated use. Health problems can arise from drinking or being exposed to recycled water if it contains disease causing organisms or other contaminants.[143] This means it is important for users to understand the risks and to take precautions to make sure users are not exposed.

Recycled water is most commonly used for non-potable water (not for drinking) uses such as agriculture or landscape irrigation, cooling water, or toilet flushing. Although most waste recycling projects have been developed to meet non-potable water demands, there are many projects that use recycled water for potable purposes. Recycled water can also be used for groundwater recharge. This means that recycled water is spread or

[139] Guidelines for the Treatment and Use of Recycled Water. PDF. Hawaii State Department of Health Wastewater Branch, May 15, 2002.

[140] "On-Site Alternate Water Sources & Use Introduction." Alternative Water Sources Intro. Accessed October 28, 2016. http://www.allianceforwaterefficiency.org/Alternative_Water_Sources_Intro.aspx.

[141] "Water Recycling and Reuse: The Environmental Benefits." EPA. Accessed October 29, 2016. https://www3.epa.gov/region9/water/recycling/.

[142] "Water Recycling and Reuse: The Environmental Benefits." EPA. Accessed October 29, 2016. https://www3.epa.gov/region9/water/recycling/.

[143] "Water Recycling and Reuse: The Environmental Benefits." EPA. Accessed October 29, 2016. https://www3.epa.gov/region9/water/recycling/.

injected into groundwater aquifers to augment ground water supplies or prevent saltwater intrusion in coastal areas.[144]

Recycling water can also provide environmental benefits such as decreasing the diversion of water from sensitive ecosystems. Plants, wildlife and fish need adequate water flows to their habitats to live and reproduce and when that flow is altered it can cause deterioration of water quality and ecosystem health. Water is often diverted for agriculture, urban and industrial purposes. Reusing water can supplement water demands and increase the amount of water for the environment and sensitive ecosystems that rely on this water. Recycling water can also decrease wastewater discharges and reduce and prevent pollution.[145] Wastewater or polluted water is often discharged to oceans, river, and other water bodies. Using recycled water can reduce the amount of polluted water that is entering these water bodies. Recycled water can contain higher levels of nutrients such as nitrogen than potable water which is sometimes beneficial for plants. Recycled water can also be used to create or enhance wetlands and riparian habitats. Water flow from recycled water can be used to augment water diversion and sustain and improve the aquatic and wildlife habitat of streams.

Recycled water can also save energy and water and in turn save money. As demands for water increase, more water is extracted, treated and transported often over great distances and requires a lot of energy.[146] If the local source is groundwater, the level of groundwater decreases as more water is removed. This increases the energy needed to pump water to the surface. Recycling water on site reduces the energy that is needed to move water over longer distances or pump water from within an aquifer.

Water reuse guidelines under the Hawaii State Department of Health is divided into two volumes, recycled water facilities and recycled water projects. Recycled water facilities, addresses technical requirements that must be met for the various qualities of recycled water as well as requirements to construct or modify a wastewater reclamation facility (WWRF).[147] Recycled water projects covers the application process to use recycled water for purposes such as irrigation, dust control, cleaning and firefighting and establishes best management practices that apply to the end user.[148] This paper will be focusing on recycled water projects.

[144] "Water Recycling and Reuse: The Environmental Benefits." EPA. Accessed October 29, 2016. https://www3.epa.gov/region9/water/recycling/.
[145] "Water Recycling and Reuse: The Environmental Benefits." EPA. Accessed October 29, 2016. https://www3.epa.gov/region9/water/recycling/.
[146] "Water Recycling and Reuse: The Environmental Benefits." EPA. Accessed October 29, 2016. https://www3.epa.gov/region9/water/recycling/.
[147] Reuse Guidelines. PDF. Hawaii State Department of Health Wastewater Branch, January 2016.
[148] Reuse Guidelines. PDF. Hawaii State Department of Health Wastewater Branch, January 2016.

5.2 Storm Water

5.2.1 Introduction

Storm water refers to rainwater that is collected from non-roof surfaces such as parking lots, hardscapes, and landscapes surrounding urban buildings. Managing storm water in urban environments is becoming increasingly important as urban sprawl and non-porous surfaces increase. Storm water runoff picks up pollutants like trash, chemical, oils, and dirt/ sediments that can harm rivers, streams, lakes and coastal water. It is important to be cautious when using storm water as an alternative water supply as the water may collect pollutants as it travels across landscapes and hardscapes. The quality of storm water varies from different sites and water quality determines the appropriate uses or if water treatment is needed before the water is used.[149]

5.2.2 Low Impact Development

Low impact development (LID) is a term that is used to describe a land use planning and engineering design approach to managing storm water runoff. Low impact development is a basic principle that is modeled after nature. LID includes a variety of practices that mimic natural drainage processes to manage storm water. It seeks to manage rainfall at the source and mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source.[150] These principles seek to create functional and appealing site drainage that treat storm water as a resource rather than a waste product. Instead of conveying, managing and treating storm water in large costly end of pipe facilities located at the bottom of drainage areas, low impact development strives to retain rainwater and lets it seep into the ground rather than allowing it to run into the storm drains where it would contribute to flooding as well as pollution problems. LID addresses storm water through small cost effective landscape features located at the lot level. By using and implementing low impact development principles and practices, water can be managed so that the impact of built areas is reduced and the natural movement of water within an ecosystem is promoted. When applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions. LID is a versatile approach that can be applied to new development, urban retrofits, redevelopment and revitalization projects.

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[149] "On-Site Alternate Water Sources & Use Introduction." Alternative Water Sources Intro. Accessed October 28, 2016. http://www.allianceforwaterefficiency.org/Alternative_Water_Sources_Intro.aspx.
[150] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

Figure 18: Low Impact Development Diagram[151]

The natural hydrology or flow of water through a watershed is shaped over centuries under location specific conditions to form a balanced and efficient system. During a storm event, water hits the ground and either infiltrates the surface or flows overland. Flowing water can pick up and carry sediments and pollutants which in turn can degrade water quality and habitats in surface waters. When surfaces that are, non-porous or hardened are constructed, such as roads, parking lots and rooftops, the movement of water is altered and the amount of runoff increases and infiltration decreases. Rainfall therefore is unable to soak through these surfaces; the water then flows over the surfaces quickly picking up pollutants that then enter storm drains or ditches, these then empty into local waterways without treatment. Excessive runoff conditions are intensified by impervious surfaces and can cause damage such as erosion of the land or in our streams. Conventional storm water conveyance systems are designed to collect, convey and discharge runoff as efficiently as possible and while this creates a highly efficient drainage system, this also decreases groundwater recharge, increases runoff volume and changes the timing, frequency and rate of discharge. These changes can cause flooding, water quality degradation, stream erosion and the need to construct end of pipe BMPs.[152] Low impact development helps to increase infiltration, filtration and storage while also reducing pollutants.

In comparison, a local undeveloped watershed, that has vegetation covered soil, is able to soak up rainfall rather than allowing it to run off and collect pollutants. Water is then able to be filtered through the soil and recharge the groundwater table or be slowly released into local waterways. An undeveloped watershed can provide water that is clean

[151] "Low Impact Development (LID) Urban Design Tools." Low Impact Development (LID) Urban Design Tools. Accessed October 29, 2016. http://lid-stormwater.net/.
[152] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

and safe. Low impact development strategies try to mimic hydrologic functions of storage, infiltration and groundwater recharge of an undeveloped watershed by applying micro scale storm water retention and detention areas, reduction of impervious surfaces and the lengthening of flow paths and runoff time.

Figure 19: Impervious vs. Pervious Surfaces[153]

By adding LID solutions, communities can function similar to undeveloped watersheds while still allowing for development to occur. LID practices such as natural or manmade swales, vegetated areas, and constructed wetlands can capture and retain water onsite where water can soak into soil and be naturally filtered. LID practices can also provide a high quality of water treatment controls due to runoff volume control of the “first flush” which is the first ½ inch of runoff which contains the highest volume of pollutants.[154] Pollutant loadings are concentrated in the "first flush" of runoff from impervious surfaces and contain grease, oil, nutrients (nitrogen and phosphorous), sediments and heavy metals.

LID also has a number of environmental as well as economic benefits. Applying LID measures can result in less disturbance of the development area, conservation of natural features and can be less cost intensive than traditional storm water control mechanisms. Additional benefits include a reduced number of flooding events, restored aquatic habitat, improved groundwater recharge, and enhanced neighborhood beauty. LID’s economic benefits include reduced cost of storm water infrastructure, reduced

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[153] "Stormwater Central." Stormwater Central. 1970. Accessed October 29, 2016. http://managingstormwater.blogspot.com/.
[154] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

storm water utility fees, increased land value and decreased spending on current and future environmental conservation programs.[155] Using LID principles also shows cost savings not only for construction but also for long term maintenance and life cycle considerations. Some additional costs that can come with implementing LID can include higher installation costs and increased landscape maintenance costs.

Storm water runoff can collect pollutants such as oil, bacteria, sediments, metals, hydrocarbons and some nutrients for impervious surfaces which is then discharged into surface waters. LID practices can decrease the amount of pollutants from storm water entering local waters. The improved water quality can increase property value as well as reducing government clean-up costs.

LID practices can also reduce the number of flooding events. When using ditches, or drains to divert runoff to local waterways, flooding can occur when high volumes of storm water enter surface water quickly. By incorporating LID practices, the volume and speed of the water can be reduced to decrease the costs and damages caused by flooding.

LID can also aid in restoring aquatic habitats. Rapidly moving storm water damages and erodes stream banks and channels which damages the habitat for fish and other aquatic life. By using LID practices the amount of storm water that enters the water systems can be reduced and help to maintain the natural stream channel functions and habitat.

Applying LID practices can also result in improved groundwater recharge. Runoff that quickly flows over paved surfaces and enters ditches and drains into surface water cannot soak into the ground. LID practices retain water on site and allow water to enter the ground and be filtered by the soil where it can seep down into the groundwater table.

When implemented broadly, LID can also mitigate the urban heat island effect (by infiltrating water running off hot pavements and shading and minimizing impervious surfaces), mitigate climate change (by sequestering carbon in plants), save energy (from green roofs, tree shading, and reduced/ avoided water treatment costs), reduce air pollution (by avoiding power plant emissions and reducing ground-level ozone), increase property values (by improving neighborhood aesthetics and connecting the built and natural environments), and increased groundwater recharge.

[155] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

Bio retention

Figure 20: Bio retention Area[156]

Bio retention areas are landscaping features that are adapted to treat storm water runoff. Bio retention basins are landscaped depressions or shallow basins that are used to slow and treat on site storm water runoff. Storm water can be directed to the basin and then allowed to percolate through the system. The slowed cleaned water is allowed to infiltrate soils or can be directed into a nearby storm drain or receiving waters.[157] Bio retention systems are generally used on small sites but can be applied to a wide range of projects and can be applied in many climate and geologic situations with minor design modifications.

Bio retention systems are designed based on soil types, conditions and land uses. Bio retention areas can be composed of a mixture of functional components that each perform a different function in removing pollutants and attenuating storm water runoff. Six typical components that are found in bio retention cells[158]:

grass buffer strips: grass buffer strips help to reduce runoff velocity and filter particulate manner.

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[156] "LID Urban Design Tools - Bio retention." LID Urban Design Tools - Bio retention. Accessed November 20, 2016. http://www.lid-stormwater.net/bio_benefits.htm.

[157] "Stormwater Management - Tools for Conservation Design." Stormwater Management - Tools for Conservation Design. Accessed December 06, 2016. http://www.lakesuperiorstreams.org/stormwater/toolkit/tools.html.

[158] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

sand bed: provides aeration and drainage of the planting soil and assists in the flushing of pollutants from soil materials.

ponding area: provides storage of excess runoff and helps with the settling of particulates and evaporation of excess water.

organic layer: decomposes organic material by providing a medium of biological growth (such as microorganisms) to degrade petroleum based pollutants. It also filters pollutants and prevents soil erosion.

planting soil: provides an area for storm water storage and nutrient uptake by plants. planting soils also contain some clays which absorb pollutants such as hydrocarbons, heavy metals and nutrients.

vegetation (plants): functions in the removal of water through evapotranspiration and pollutant removal through nutrient cycling.

Rain Gardens

Figure 21: Rain Garden[159]

Rain gardens are gardens that contain flowering plants and grasses (preferably native species of both) that can survive in soil that is soaked with water from rain

[159] Ryan, Mary Ann. Rain Garden. JPEG. The Master Gardeners.

storms.[160] These gardens collect and slow storm water runoff and increases its infiltration into the soil. This reduces the amount of water that enters the storm drains and protects streams and other water bodies from pollutants that are present in storm water.

Rain gardens should be located at least ten feet from a house or building and be placed in a low point to which storm water from downspouts can be directed.[161] Rain gardens should be covered with mulch to help to reduce weeds as well as retaining moisture in the garden. It is also important for weeding to be performed while the garden is being established. Native plants can also be used in rain gardens since they are already adapted to soil and temperature conditions of the area.

Grass Swales

Figure 22: Grass Swale[162]

Grass swales are shallow open channels that are lined with dense vegetation that are designed to treat, attenuate, and convey excess runoff. The swale is usually vegetated

[160] "Stormwater Management - Tools for Conservation Design." Stormwater Management - Tools for Conservation Design. Accessed December 06, 2016. http://www.lakesuperiorstreams.org/stormwater/toolkit/tools.html.

[161] "Stormwater Management - Tools for Conservation Design." Stormwater Management - Tools for Conservation Design. Accessed December 06, 2016. http://www.lakesuperiorstreams.org/stormwater/toolkit/tools.html.

[162] "Vermont Low Impact Development Guide for Residential and Small Sites." Accessed November 20, 2016. https://anrweb.vt.gov/PubDocs/DEC/WSMD/stormwater/docs/sw_LID Guide.pdf.

with flood tolerant, erosion resistant plants.[163] Grass swales or channels are flexible in layout and design, are relatively inexpensive and are adaptable to a variety of site conditions. Grass swales are used as a mechanism to reduce runoff velocity and serve as filtration/infiltration devices.[164] Swales are primarily used along residential streets and highways. Swales can replace curb or gutter systems. Although they take up more space, they are able to manage runoff better. Grass channels are most effective when the flow depth is minimized and detention time is maximized. Open channel systems are most appropriate for smaller drainage areas with mildly sloping topography. Decreasing the slope or providing dense cover will help with stability and pollutant removal effectiveness. Periodic mowing and removal of sediments are the most significant maintenance requirement of swales.

Vegetated Roof Covers

Figure 23: Vegetated Roof Cover Section[165]

[163] "Stormwater Management - Tools for Conservation Design." Stormwater Management - Tools for Conservation Design. Accessed December 06, 2016. http://www.lakesuperiorstreams.org/stormwater/toolkit/tools.html.

[164] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

[165] "LID Urban Design Tools - Bio retention." LID Urban Design Tools - Bio retention. Accessed November 20, 2016. http://www.lid-stormwater.net/bio_benefits.htm.

Vegetative roof covers or green roofs are an effective means of reducing urban storm water runoff since it reduces the amount of impervious surfaces in urban areas. A green roof is a multilayered constructed material that consists of a vegetative layer, media, a geotextile layer and a synthetic drain layer.[166] Green roofs are effective in older urban areas with combined sewer overflow problems due to the high level of imperviousness. Green roofs in urban areas offer a variety of benefits including extending the life of roofs, reducing energy costs and conserving land that would otherwise be used for storm water runoff controls. Green roofs also mitigate the "heat island" effect as well as reducing CO2 impact and reducing the volume and peak rates of storm water.

Permeable Pavements

Figure 24: Permeable Pavement[167]

Porous pavement is a permeable pavement surface with an underlying stone reservoir that temporarily stores surface runoff before infiltration into the subsoil.[168] Permeable pavements can be an effective way to reduce the amount of imperviousness in an urban area. The porous surface can be used to replace traditional pavement in areas such as parking lots and allow runoff to directly infiltrate directly into the soils and receive water quality treatment. Porous pavements are best suited for areas with low traffic such as parking lots and sidewalks. Permeable pavements allow storm water to infiltrate into underlying soils promoting pollution treatment and recharging aquifers as

[166] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.
[167] "Why Choose Permeable Pavers?" The Best Garden Center in Binghamton NY and Broome County Hillside Garden Center. Accessed November 20, 2016. http://hillsidegardencenter.com/why-choose-permeable-pavers/.
[168] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

opposed to producing large volumes of rainfall runoff requiring conveyance and treatment. Various forms of pervious pavement include porous concrete, porous asphalt, permeable pavers and reinforced turf. Pervious pavement offers dual use by serving as a pavement structure as well as a storm water management device.

Constructed Wetlands

Figure 25: Constructed Wetland at Sidwell Friends School[169]

A constructed wetland can remove sediments and other common storm water pollutants as well as enhancing the visual appeal of the landscape. Constructed wetlands are treatment systems which use natural processes involving wetland vegetation, soils and their associated microbial assemblages to improve water quality.[170] Constructed wetlands can also be used to reduce peak flows and runoff volumes in general. The wetland utilizes a variety of biological, physical and chemical processes for pollutant removal through uptake by vegetation and microorganisms.[171] Wetlands provide a number of functions other than water quality improvement including flood storage and desynchronization of storm rainfall and surface runoff, cycling of nutrients and other materials and aesthetic

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[169] "Sidwell Friends School." Designing Our Future: Sustainable Landscapes. Accessed November 20, 2016. https://www.asla.org/sustainablelandscapes/sidwell.html.

[170] "Constructed Wetlands." EPA. Accessed December 03, 2016. https://www.epa.gov/wetlands/constructed-wetlands.

[171] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

and landscape enhancements. In addition, wetlands can provide wildlife habitat as well as improving water quality. Constructed wetlands can be used to treat various types of wastewater as well as storm water and agricultural runoff. Many plants absorb acid and keep the water safe for wetland inhabitants.

Roof Top Disconnection and Rain Barrels

Figure 26: Rain Barrel[172]

Roof top disconnection refers to disconnecting the roof gutter downspouts from the sewer system.[173] This allows roof water to drain to lawns, gardens or even to a rain barrel for collection. This is a natural way to manage roof runoff since it allows water to soak into the ground while also allowing plants and soils to filter pollutants. Redirecting the flow of the water to a grassy area or garden is an easy way to keep runoff onsite as well as reducing runoff impacts to surface water.

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[172] "Vermont Low Impact Development Guide for Residential and Small Sites." Accessed November 20, 2016. https://anrweb.vt.gov/PubDocs/DEC/WSMD/stormwater/docs/sw_LID Guide.pdf.

[173] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.

Water should be drained at least five feet away from the house so an extension should be designed accordingly.[174] Using a splash block at the end of the downspout will help to direct water further away from the house. Placing gravel at the end of the splash block can help to slow the velocity of the water and prevent localized erosion. Gravel can also give the water additional time to infiltrate.

Instead of allowing water to flow into the ground, a rain barrel can be designed to intercept and store runoff from rooftops. This water can then be used for reuse such as irrigating lawns and plants. The Department of Environmental Conservation recommends double rain barrels or cistern use as these can store a larger amount of water which increases their value as a water quality practice and when greater storage is necessary and less water is available.[175] Rain barrels should be installed near the collection point or downspout of the building and be drained or used between storm events to prevent overflow. Downspouts should be piped directly into the rain barrel through a screen to eliminate debris and prevent insect access. The overflow outlet should be about three inches below the top of the rain barrel and should connect to the next barrel. The overflow from the second barrel should be directed to an infiltration area. Gravel or a splash block should be positioned at the overflow outlet similar to a downspout disconnect to allow water that overflows to infiltrate.

Cisterns should be designed for overflow during large events. Cisterns reduce the need for potable water and provides supplemental non-potable water supply. Cisterns are also applicable to a variety of projects. Cisterns can however only manage small storm events depending on their size.

5.3 Greywater

Residential wastewater can be divided into two categories, black water and greywater. Blackwater, as defined by the State of Hawaii Department of Health Wastewater Branch is wastewater discharged from toilets and urinals and food preparation sinks (kitchen sinks).[176] This water should not be used for irrigation due to the high risk of contamination from bacteria, viruses, and other pathogens. Blackwater contains higher concentrations of nitrogen, organic matter and pathogens than greywater. Greywater is defined as wastewater discharged from showers, bathtubs, handwashing lavatories, wastewater that has not contacted toilet waste, sinks (not used for disposal of hazardous, toxic materials, food preparation or food disposal), and clothes washing machines (excluding wash water with human excrete e.g., diapers).[177]

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[174] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.
[175] "Low Impact Development (LID): A Literature Review." October 2000. Accessed October 29, 2016. http://www.lowimpactdevelopment.org/pubs/LID_litreview.pdf.
[176] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[177] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.

Figure 27: Suggested Treatment and Usage of Greywater[178]

Grey water can be used to meet the demand for landscaping. Diverting greywater to subsurface irrigation reduces the amount of wastewater that enters the wastewater system. Some of the constituents from cleaning agents such as detergents, soaps and solvents can be considered fertilizer for plants and phosphorous, nitrogen, and potassium are some things found in grey water that plants need to survive.[179]

When reusing greywater, there are health and safety issues that are involved. The contaminants found in greywater can be harmful to your health if ingested or if there is physical contact with the greywater especially through skin abrasions. People that are reusing greywater need to understand the risks and safety issues that are associated with it.

Some precautions should be taken when using grey water. These include using spray irrigations to apply greywater, the application of greywater should be done by utilizing a subsurface system.[180] Greywater should also only be applied to areas that receive little to no pedestrian traffic. Minimizing the exposure of greywater to the public is important in reducing the risk of contact. It is also important that greywater is not used to irrigate gardens that contain edible fruit or vegetable where the consumed portion of the plants rest on the ground. Greywater should also not be used to wash down driveways, patios or other impervious surfaces as this leads to risk of human exposure. When handling components of the greywater system, latex or surgical gloves should be

[178] "Water Recycling and Reuse: The Environmental Benefits." EPA. Accessed October 29, 2016. https://www3.epa.gov/region9/water/recycling/.
[179] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[180] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.

worn to perform maintenance activities. If someone in the household comes down with a contaminated sickness it would be wise to divert the greywater to the sewer system until the individual has recuperated to avoid anyone coming into contact with the greywater as they could be exposed to disease causing organisms. Water that is used to wash clothing that might be soiled with pesticides or other toxic chemicals should not be discharged into the greywater system. The greywater system should also have regular operational and maintenance checks. The system should also be monitored and adjusted to ensure that ponding does not occur. Users should also understand that whatever they wash down the drain will end up in the landscape. Plants that cannot tolerate high levels of chlorides, sodium, borax and sulfates should not be irrigated using grey water. Not all plants grow in the same climates and soil types thus not all plants will thrive when irrigated with greywater. Plants that grow best in acidic soils should not be irrigated with greywater as greywater makes the soil more alkaline.

Figure 28: Examples of Plants Tolerant/Not Tolerant to Gray Water[181]

[181] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.

Figure 29: Examples of Local Plants Tolerant to Gray Water[182]

Greywater can be used for irrigation in a subsurface system. Greywater can also be used to irrigate established lawns and plans. It should not be used where potential runoff and ponding exists such as in barren areas or where there are seedlings. Greywater should also not be used to irrigate root crops or vegetables that will be eaten raw.

Greywater should avoid soaps, detergents and cleaners that contain: bleaches, softeners, whitening ingredients, enzymatic powers, borax, peri oxygen, sodium perborate, petroleum distillate and alkyl benzene sodium trypochlorite.[183]

Alkalinity refers to the relative amounts of alkaline chemicals in a solution. Sodium, potassium and calcium are alkaline chemicals and plants do not tolerate high concentrations of alkali salts.[184]

Boron is considered a plant micronutrient and is only required in small amounts.[185] Most soils provide adequate amounts of boron and only concentrations that are slightly higher can cause severe injury or death to plants.

Conductivity is a measure of the amount of dissolved chemicals in a solution.[186] These chemicals can be beneficial or harmful. The higher the conductivity the more dissolved salts and minerals are present. The higher the concentration of dissolved salts and minerals in the water, the greater the potential for adverse effects on the environment and plant health.

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[182] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[183] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[184] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[185] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[186] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.

Sodium can reduce the plant's ability to take up water from soil and too much sodium can destroy the structure of clay soils making them slick and greasy by removing air spaces which prevents good drainage.[187]

Phosphate is a plant food and is added to soil as a fertilizer. Many forms of phosphate are not readily useable by plants and soils.

Chlorine is found in bleach and detergents and is generally expended in the washing process.[188] There are however times when not all of the chlorine is used up in the washing process.

High levels of sodium, boron and chlorine in gray water can cause damage to plants. Signs of excessive chlorine and sodium include leaf burn, yellowing leaves and twigs dying. By reducing the amount of chlorine, sodium and boron in grey water the potential for plant damage will be reduced. It is important to know what is contained in the products that are used to clean, bathe, launder and are otherwise washed down the drain.

Sodium can be reduced by choosing soaps or detergents that do not contain sodium rich fillers as these fillers do not affect the cleaning. Concentrated detergents typically contain less sodium as they do not usually contain fillers. Most household cleaning products contain chlorine and while most of it is expended during the cleaning process, it is best that its use be kept to a minimum to prevent high concentrations of chlorine in the system.

Irrigating with greywater can have long term effects such as increased pH levels or alkalinity and an accumulation of sodium. Sodium can damage soil structure over time and can inhibit a soils ability to accept water. To prevent significant damage to the soil, users should measure the pH level of the soil periodically. Alkaline soil will have a pH level of 7.1 or higher and pH levels above 7.5 are considered high and should be monitored.[189] To reduce the pH level of the soil, agricultural sulfur or acidic fertilized can be added to the soil. Mixing in organic matter can help to counteract the effects of sodium buildup and help restore the soil structure and water absorption rate.

For the safe and effective use of graywater, black water cannot come into contact with the grey water. Blackwater can be treated with an individual wastewater system or be diverted to an available sewer system.

The easiest water to use greywater is to pipe it directly outside and to use it to water ornamental plants or fruit trees.[190]

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[187] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[188] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[189] Guidelines for the Reuse of Greywater. PDF. Department of Health, June 22, 2009.
[190] "Greywater Reuse." Greywater Action. Accessed October 28, 2016. http://greywateraction.org/contentabout-greywater-reuse/.

5.4 Blackwater/Wastewater

Municipal wastewater reuse offers the potential to significantly increase the nation's total available water resources. Approximately 12 billion gallons of municipal wastewater effluent is discharged each day to an ocean or estuary out of the 32 billion gallons per day discharged nationwide.[191] Reusing these coastal discharges would amount to about 6 percent of the estimated total U.S. water use or 27 percent of public supply.[192]

Figure 30: Suggested Treatment and Uses for Blackwater[193]

Treatment processes in wastewater reclamation are employed either singly or in combination to achieve reclaimed water quality goals. Wastewater treatment in the United States typically includes preliminary treatment steps in addition to primary and secondary treatment. Preliminary treatment steps include the measuring of the flow coming into the plant, screening out large solid materials, and grit removal to protect equipment against unnecessary wear. Secondary treatment processes remove total

[191] Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater. Washington, D.C.: National Academies Press, 2012.
[192] Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater. Washington, D.C.: National Academies Press, 2012.
[193] "Water Recycling and Reuse: The Environmental Benefits." EPA. Accessed October 29, 2016. https://www3.epa.gov/region9/water/recycling/.

suspended solids, dissolved organic matter (measured as biochemical oxygen demand), and with increasing frequency, nutrients.[194] Secondary processes consist of aerated activated sludge basins with return activated sludge or fixed media filters with recycle flow such as trickling filters and rotating bio contractors, followed by a final solid separation via settling or membrane filtration and disinfection.[195]

Disinfection

Disinfection processes are deliberately designed for the reduction of pathogens. Pathogens are generally targeted for the reduction of bacteria, viruses, and protozoa. Common agents that are used for disinfection in wastewater are chlorine and ultraviolet irradiation.

5.5 Uses of Reused Water

Suitable uses of recycled water depend on its quality and application method. Suitable uses are separated into three categories R-1, R-2 and R-3.

R-1 refers to recycled water where the wastewater has undergone oxidation, filtration and disinfection. R-1 is considered the highest grade of recycled water. Suitable uses for the R-1 category[196]:

- Irrigation: landscape and agricultural irrigation using spray, surface drip or subsurface irrigation
- Homes: irrigation of a home on agricultural land or condominium property regime provided there is a recycled manager. Irrigation of single family residential homes with a recycled water manager is prohibited.
- Farm animals: drinking water for livestock and poultry with the exception of dairy animals that produce milk for human consumption.
- Supply to impoundments
    - Restricted recreational impoundments such as golf course hazards, landscape water features, fountains, waterfalls;
    - Irrigation storage reservoirs and ponds; and
    - Fish hatchery basins
- Dust control: dampening, wet sweeping and/or wash down of streets, roads, parking lots, walkways, etc.
- Cleaning:
    - Flushing toilets, urinals, and sanitary sewers where permitted by the applicable county plumbing code.
    - High pressure water cleaning of surfaces and

[194] Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater. Washington, D.C.: National Academies Press, 2012.
[195] Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater. Washington, D.C.: National Academies Press, 2012.
[196] Reuse Guidelines. PDF. Hawaii State Department of Health Wastewater Branch, January 2016.

- Agricultural cleaning to wash down animals such as cattle, livestock, animal pens and housing
- Cooling of power equipment while cutting, coring or drilling pavements, walls and other hard surfaces
- Water jetting to consolidate backfill material around piping for recycled water, non-potable water, sewage, storm drains, gas, and electrical conduits
- Washing aggregate and concrete manufacturing
- Boiler feed water
- Industrial processes and industrial cooling
- Firefighting and
- Test water for gas pipeline testing

R-2 refers to recycled water where the wastewater has undergone oxidation and disinfection. R-2 Suitable uses[197]:

- Subsurface drip irrigation is allowed for
    - Golf course landscaping
    - Parks, athletic fields, school yards, cemeteries
    - Above ground food crops (such as fruit trees) where the edible portion of the crop has minimal contact with the recycled water
    - Impoundments without fountains or any other water feature that generate spray or mist
    - Landscapes around certain residential property such as condominiums that have a recycled water manager responsible for the landscape irrigation and
    - Freeway, roadside, and medical strip landing
- Surface drip or subsurface drip irrigation is allowed for
    - Non-edible vegetation in areas with limited public access
    - Sod farms
    - Ornamental plants for commercial use
    - Fodder, fiber, and seed crops not consumed by humans and
    - Timber and trees not bearing food crops
- Although R-2 spray irrigation is generally prohibited, R-2 spray irrigation may be allowed provided an adequate buffer exists between the areas being sprays and the adjacent residential or publicly accessible area. An adequate buffer can be accomplished by
    - Separation distance of 500 feet
    - Physical barrier such as a wall or cliff
    - Tall and dense vegetation or
    - Irrigating with potable water within the buffer area

[197] Reuse Guidelines. PDF. Hawaii State Department of Health Wastewater Branch, January 2016.

R-3 refers to recycled water where the wastewater has undergone oxidation only. This is the lowest grade of recycled water. R-3 Suitable uses[198]:

- R-3 drip or subsurface irrigation if allowed for:
    - Non-edible vegetation in areas with limited public access
    - Fodder, fiber and seed crops not consumed by humans and
    - Timber and trees not bearing food crops

Recycled water can only be applied in approved areas within the state. Areas fall into three categories: unrestricted areas; where recycled water application is unconditionally allowed, conditional areas where recycled water application is currently allowed but may be subject to monitoring requirements or restrictions and restricted areas where recycled water application is prohibited.

Figure 31: Recycled Water Use Map[199]

5.6 Conclusion

Water reuse in Hawaii can be a way to satisfy water demands with non-potable water. In drier areas or areas that do not receive a lot of rainfall, reusing water can be a good way to use less potable water and conserve water when there is not enough water available. In wetter areas, reusing water can help to offset potable water demands. Recycled water can satisfy most water demands as long as it is adequately treated to ensure water quality that is appropriate for the use. If there is a chance for human contact,

[198] Reuse Guidelines. PDF. Hawaii State Department of Health Wastewater Branch, January 2016.
[199] Guidelines for the Treatment and Use of Recycled Water. PDF. Hawaii State Department of Health Wastewater Branch, May 15, 2002.

more treatment is required. Water reuse can have additional benefits other than offsetting potable water including decreasing and preventing pollution. Water reuse can also save electricity since it reduces the amount of water that needs to be treated, transported and extracted which is all energy intensive.

Incorporating strategies such as low impact development within a project can reduce the amount of potable water used as well as providing opportunities for learning throughout the campus. Since many reuse strategies can be observed, students can learn from these systems and begin to take these principles home with them. Implementing water reuse strategies can reduce the amount of potable water that is needed while also providing learning opportunities for the students. Water reuse strategies mentioned in the paper can have the greatest impact on the students since it is the most engaging and interactive. Water reuse strategies can be incorporated into school curriculum to help students to better understand and learn so that it can be applied in their lives at home and in the future.

6. Design Strategies

The following is a list of strategies in water efficiency, conservation and reuse that can be incorporated into projects. It also includes a description of the strategy, benefits and drawbacks, as well as information regarding cost, installation and maintenance. It can be used as an overview to help determine which strategies may be best suited for different projects. The following list of design strategies can be used by design professionals and administrators. The design strategies can be used in conjunction with the design guidelines to decreasing water use in schools in Hawaii.

Water Efficiency Strategies								
	Description	Additional Requirements	Benefits	Drawbacks	Installation	Cost	Savings	Maintenance
Low Volume Gravity Tank Toilets	1.6 gpf gravity tank toilets work on the same principles as the 3.5 and 5.0 gpf fixtures	Minimum water pressure of 10 to 15 pounds per square inch (psi) to work properly	-Equal if not improved performance compared to a high volume gravity tank toilet -Smaller tank uses less water than high volume toilets	-Prone to leakage, particularly when operated with corrosive water or poor quality mechanical parts inside the tank	The installation of gravity tank based low volume and dual flush toilets are compatible with most sanitary installations and are suitable for the replacement of toilets with high water demand	$75 to $225	494 gal per male and 1,482 gal per female	-Should be checked regularly for leaks and to ensure they are properly adjusted to operate within their design flush volume -Should be inspected at least twice a year and require ongoing maintenance to minimize water losses from leakage
Dual Flush Toilets	flushes for liquid only wastes are activated by depressing the handle in one direction for minimal flush (1.0 gpf or less) and flushes for solid wastes are activated by depressing the handle in another direction for a full flush		-Allows the user to choose from two different flush types -Uses less water for liquid wastes	-Can clog or require double flushing if not flushed properly	The installation of gravity tank based low volume and dual flush toilets are compatible with most sanitary installations and are suitable for the replacement of toilets with high water demand	$195 to $260	494 gal per male and 1,482 gal per female	-Should be checked regularly for leaks and to ensure they are properly adjusted to operate within their design flush volume -Signs or arrows may need to be posted to instruct users on how to properly flush the toilet
Low Volume Flushometer Tank (Pressurized) Toilets	WaterSense labeled flushometer valve toilets use no more than 1.28 gpf. When a flushometer tank toilet is flushed, compressed air forces the water out of the tank and into the bowl inducing symphonic action that pushes the contents of the bowl down the drain	Requires a relatively constant and comparably high water pressure from piped water supply for operation requires at least 25 psi to run well	-Provides higher velocity flushes -Better bowl cleaning than some gravity fixtures which reduces the chance of double flushing, cleaning, and clogs -Clears the bowl in less than 10 seconds -Virtually leak proof	-Tend to be noisier than gravity toilets -When flushed, needs 60 to 90 seconds to complete the flushing cycle and refill the tank before being flushed again -Replacement parts may not be readily available from all home and plumbing supply stores	The installation of gravity tank based low volume and dual flush toilets are compatible with most sanitary installations and are suitable for the replacement of toilets with high water demand	$150 to $650	494 gal per male and 1,482 gal per female	-Should be checked regularly for leaks and to ensure they are properly adjusted to operate within their design flush volume -Signs or arrows may need to be posted to instruct users on how to properly flush the toilet
Incinerator Toilets	Incinerator toilets use high temperature electric or propane heat to burn wastes		-Water and sewer cost savings -Reduced sewer and septic system needs -Do not need sewer or septic system hookups -Reduces water use and leakage by 100%	-May require electricity to operate -Additional operating costs for electricity and plastic liners	Installation of electrical and solar system typically will require design and construction modifications of existing buildings to accommodate vents and electrical requirements	$900 to $1,800	910 gal per male per year and 2,730 per gal per female per year	-Incinerator toilets require cleaning on the seat and exterior of the fixture

Water Efficiency Strategies								
	Description	Additional Requirements	Benefits	Drawbacks	Installation	Cost	Savings	Maintenance
Composting Toilets	Composting toilets are not flushed and need virtually no water to convert human waste into hummus	Needs adequate warmth (65 degrees F or higher) and circulation to evaporate water from waste	-Water and sewer cost savings -Reduced sewer and septic system needs -Do not need sewer or septic system hookups -reduces water use and leakage by 100%	-Removal and off site disposal costs may be incurred for waste material collected -May require electricity to operate -Need organic bulk material such as wood shavings, mulches, sawdust, etc. -Need adequate warmth and air circulation -Additional operating costs	Installation of a composting toilet system in an existing building include toilets, composting storage container(including electric variable speed fan to provide oxygen to the composting waste and to prevent odors from exiting through the toilet instead of the vent stack), vent system and building alterations.	$5,000 to $20,000	910 gal per male per year and 2,730 per gal per female per year	-Require periodic if not daily maintenance to ensure that waste is decomposing properly, adequate carbon materials are added and mixed, the liquid chamber is drained and insect and odor control are adequate, depending on the amount of waste generated
Low Volume Flushometer Valve Urinals	Use 1.0 gpf or less		-Water and sewer cost savings -Reduced sewer and septic system needs		Can often be installed to replace high volume urinals with no modifications to the bowl or to wall or floor connections	$200 to $450	260 gal per male per year	-No additional maintenance should be required for low volume urinals compared with high volume fixtures
Waterless Urinals	Requires no water for flushing		-Water and sewer cost savings -Reduced sewer and septic system needs -Do not need sewer or septic system hookups -Reduces water use by 100% -Do not require valve repairs or flange exchanges and there is no risk of overflow	-More prone to becoming clogged by items -Additional operating costs	Can often replace conventional fixtures that are connected to standard 2 inch drain lines	$300 to $600; trap seal liquid must be replenished after 1,500 uses at the cost of about $20	780 gal per male per year	-Maintenance must be instructed on how to replace the trap seal when necessary and how to wash the fixture because flushing without water will leave more of the bowl covered with urine residue
Composting Urinals	Require no water and are connected to composting toilet systems	Must be connected to a composting toilet system	-Water and sewer cost savings -Reduced sewer and septic system needs -Do not need sewer or septic system hookups -reduces water use by 100% -Do not require valve repairs or flange exchanges and there is no risk of overflow	-Additional initial hardware costs -Energy costs	Installation of composting urinals includes installing the urinal, composting storage container(including electric variable speed fan to provide oxygen to the composting waste and to prevent odors from exiting through the toilets or urinal instead of the vent stack, vent system, and building alteration	$250 per fixture (excluding cost of composting system)	780 gal per male per year	-Require periodic if not daily maintenance to ensure that waste is decomposing properly, adequate carbon materials are added and mixed, the liquid chamber is drained and insect and odor control are adequate, depending on the amount of waste generated,

Water Efficiency Strategies								
	Description	Additional Requirements	Benefits	Drawbacks	Installation	Cost	Savings	Maintenance
Low Volume Showerheads	Improve efficiency through features such as improved spray patterns, better mixing of air with water and narrower spray areas		-Avoided water and sewer costs -Reduced amount of energy used		-Wrap shower neck threads -Provide showerhead adapters -Check safety from scalding -Remove old showerheads	$4 to $8	322 gallons per year	-Showerheads should be checked about once a year to remove sand and grit that may accumulate and inhibit the flow of the spray
Low Volume Faucets	Low volume faucets use a maximum of 2.5 gpm at 80 psi or 2.2 gpm at 60 psi		-Avoided water and sewer costs -Reduced amount of energy used		Attention should be paid to removing existing faucets and aerators from their connections because they can become calcified and break if not handled properly	$40 to $150	1,971 gal per year	-Require periodic cleaning of grid and scale buildup that may inhibit flow
Utilize other sources of makeup water	Water from other facility equipment can be recycled and reused for makeup water	Little or no pretreatment might be necessary	-Reduces potable water used	-Water may need additional treatment	n/a	n/a	Can save up to 50% potable water	n/a
Maximize cycle of concentration of cooling tower	Determined by calculating the ratio of concentration of dissolved solids in the blowdown water compared to the makeup water		-More efficient system -Reduced water costs	-Additional monitoring and testing needed	n/a	n/a	Reduces make up water by 20% and cooling tower blowdown by 50%	-Periodic maintenance to check cycle of concentration

Water Conservation Strategies

	Description	Additional Requirements	Benefits	Drawbacks	Installation	Cost	Savings	Maintenance
Monitor for Leaks	Buildings should be monitored for leaks in plumbing or toilets		-Reduces water waste due to leaks	-Additional time needed	Users can check for leaks by turning off the water, checking the water meter, then checking back two hours later. If the meter has moved something is leaking.	n/a	n/a	-No additional maintenance needed
Adjust Irrigation Schedule	Lawns should only be watered 2-3 times a week		-Promotes deeper root growth and makes lawns healthier	-Increase time and care for maintenance during transition periods	Lawns should not watered between 9am and 5pm	n/a	Adjusting schedules can save more than 40% of water	-No additional maintenance needed
Put a Nozzle on the Hose	Putting a nozzle on the hose can reduce the amount of water used when watering plants		-Reduces water waste	-Increased cost	Most nozzles can be screwed on to hose	$10 to $20	A running hose can waste over 100 gallons in minutes	-No additional maintenance needed
Use Water Saving Irrigation Components	Water saving irrigation components such as rotary nozzles, pressure regulated spray heads/valves, rain switches or high efficiency nozzles can help to reduce the amount of water wasted		-Reduces water waste -Prevents over watering plants	-Increased cost	Would need to be compatible with existing irrigation system	n/a	n/a	-No additional maintenance needed
Install an irrigation sub meter	Sub meter will measure water consumption and provide water consumption information		-Provide users with information regarding water used for irrigation	-Increased cost	Most meters are 1 to 2 inches in diameter the rest are generally sized at 3 inches; meters are often sized to match the diameter of the water service line	about $7,000	Sub meters will allow users to better understand how much water is being used in different areas thus showing areas for reduction	-Check sub meter regularly to check for leaks or increased water use
Preserve native trees and non invasive vegetation	Preserve and use native and low water plants		-Adjusted to climate -Aesthetic benefits -Reduces use of water thirsty plants -Increased native plant diversity -Reduces need for supplemental water	-Limits design freedom -Limits choices for plantings	n/a	n/a	At least 20% reduction in water use can be expected	-Generally less maintenance will be needed
Incorporate Compost into Soils	Compost can be incorporated into soils at planting		-Compost conserves water by improving water absorption and water holding capacity -Reduces green waste going into landfill	-Increased maintenance -Increased cost	n/a	n/a	n/a	-No additional maintenance needed

Water Conservation Strategies								
	Description	Additional Requirements	Benefits	Drawbacks	Installation	Cost	Savings	Maintenance
Grass should be allowed to grow taller in summer months	Maintain the same mowing schedule with a higher mowing height		-Conserves water -Encourages deep rooting	-Additional time during transition	n/a	n/a	n/a	-No additional maintenance needed
Aerate lawns when compaction occurs	Aeration involves perforating the soil with small holes to allow air, water and nutrients to penetrate the grass		-Can improve lawn's ability to retain moisture -Helps roots grow deeply	-Additional time and maintenance needed	n/a	n/a	n/a	-Aeration should be performed when soils become compacted
Limit and separate turf areas	Turf areas should be limited to those needed for practical uses.	When selecting native or low water use grass species, consider additional factors such as shade, temperature, soil quality, drought tolerance and watering requirements	-Reduced water costs -Lower mowing cost -Less fertilizer needed -Less maintenance costs	-Limits amount of turf area available -Limits availability for flexibility	Turf should be limited to areas that will serve practical uses such as for recreation, pets, or minor foot traffic	n/a	15 to 50% water savings for landscapes	-No additional maintenance needed
Irrigate similar hydrozones	Group plants according to their water needs. Native and drought tolerant plants should be separated from thirsty ones		-Reduced water costs -Reduced water waste -Makes irrigation easier -More water efficient	-Limits design flexibility	n/a	n/a	At least 20% reduction in water use can be expected	-No additional maintenance needed

Water Reuse Strategies								
	Description	Additional Requirements	Benefits	Drawbacks	Installation	Cost	Savings	Maintenance
Bio Retention	Landscaping features that are adapted to treat storm water runoff		-Storm water treatment -Reduces amount of runoff from drainage areas -Effective removal of sediment loads, nutrients, traces of heavy metals, bacteria and organics -Flexible design layout -Relatively low maintenance	-Large and takes up more land area -Additional maintenance	Design and installation of bio retention basins can vary widely due to site conditions	$5,000 to $10,000 per acre drained or about $3-$15 per square for of bio retention surface area	n/a	-Routine inspection and attention to maintenance needs are required for new systems to continue to function properly, once established operating maintenance requirements are expected to decline
Grass Swales	Shallow open channels that are lined with dense vegetation that is designed to treat, attenuate and convey excess runoff		-Inexpensive and flexible in layout and design -Reduces runoff velocity -Serves as a filtration/infiltration device -Reduces erosion	-Take up more land area	Dependent on good engineering design. Geotechnical testing of soil to establish soil porosity and identification of close to surface bedrock. Compute water quality treatment volume for surfaces to be treated	$0.50 per square foot	n/a	-Mowing to maintain desired height of vegetation at three to four inches -Inspect for erosion -Remove trash and other debris from all parts of the swale
Vegetated Roof Covers	Multilayered construction material that consists of a vegetative layer, media, a geotextile layer and a synthetic drain layer	Additional structural support to roof sometimes needed	-Extends life of roof -Reduces energy costs -Conserves land that would otherwise be used for storm water runoff controls -Mitigate heat island effect	-Roof must be able to support additional weight from green roof components -Additional costs -May need irrigation and drainage system which requires energy and water -Additional maintenance	-Supporting roof structure -Waterproof and root repellent membrane -Insulation -Drainage, aeration, water storage and a roof barrier system -Growing medium -Plants	Intensive: $16 to $35 per square foot Extensive: $7 to $35 per square foot	n/a	-Low maintenance trimming and weeding
Porous Pavement	Permeable pavement with an underlying stone reservoir that temporarily stores storm water runoff before infiltration into subsoil		-Replenish groundwater -Reduce flooding -Allows runoff to directly infiltrate directly into soils and receive water quality treatment	-Can become clogged which disrupts the filtration process - May require additional maintenance	-Excavation and grading to prevent soil compaction -Pavement:3/4 to four inches thick -Filter course: two inches thick -Reservoir course: thickness based on runoff storage required -Filter fabric -Existing soil	$2 to $20 per square foot	n/a	-Regular maintenance of vacuuming and/or power washing are recommended

Water Reuse Strategies

	Description	Additional Requirements	Benefits	Drawbacks	Installation	Cost	Savings	Maintenance
Constructed Wetland	Treatment systems that use natural processes involving wetland vegetation, soils and their associated microbial assemblages to improve water quality	-Should be constructed on uplands and outside floodplains -Soil suitability, hydrology, vegetation, and presence of endangered species should be considered	-Reduce peak flows and runoff volumes -Water quality improvement -Flood storage and desynchronization of storm rainfall and storm runoff -Cycling of nutrients, wildlife habitat -Aesthetic and landscape enhancements	-Need for additional maintenance -Additional cost - Additional land area required	Wetlands are constructed by excavating, backfilling, grading, diking and installing water control structures to establish desired hydraulic flow patterns	Vary on location, site conditions, etc.	n/a	-Routine cleaning and maintenance -system monitoring -Sediment accumulation removal
Rain Garden	Gardens that contain flowering plants and grasses that can survive in soil that is soaked with water from rain storms	-Should be located at least ten feet from a house or building	-Collect and slow storm water runoff -Increases infiltration into soil -Reduces the amount of water that enters the storm drain and protects water bodies	-Takes up space that could be used for recreation -Additional maintenance	Rain garden surfaces need to be level and a berm approximately the height of the depth of the garden should be constructed around bottom 2/3 to 3/4 of the garden.	$5 to $15 per square foot	n/a	-Cover garden with mulch to reduce weeds -Weeding over first few years while plants become established
Roof top Disconnection and Rain Barrels	Capture rain runoff from a building's roof using the gutter and downspout system		-Help divert water from storm drain systems -Reduces pollutants and velocity of water entering system -Storage of water -Reduce water and sewer bills	-Additional cost for rain barrels -May lack aesthetic appeal -Has a limited amount of storage space	Rain barrels should be installed near collection point on the building and down spouts should be piped directly into the rain barrel through a screen	$50 to $150 per barrel	n/a	-Periodic checks throughout the season -Check that lids and hoses are properly placed and attached

7. Design Guidelines

The Design Guidelines will provide a guiding template for the architects and engineers in the development of Department of Education campus buildings. The purpose of the Design Guidelines is to supply a range of water efficiency, conservation and reuse strategies and principles as direction for future development and retrofit of Department of Education (DOE) campus buildings. The guidelines recommend strategies to reduce water use in buildings and in irrigation practices as well as methods to extend the resource through water reuse, recycling water catchment and groundwater recharge.

The guidelines provide water efficiency, conservation and reuse strategies for overall, indoor and outdoor water reduction. The water reuse section of the guidelines does not incorporate a complete set of guidelines for Blackwater and greywater reuse due to strict regulations by the Department of Health and plumbing codes. The guidelines focus on storm water and low impact development strategies.

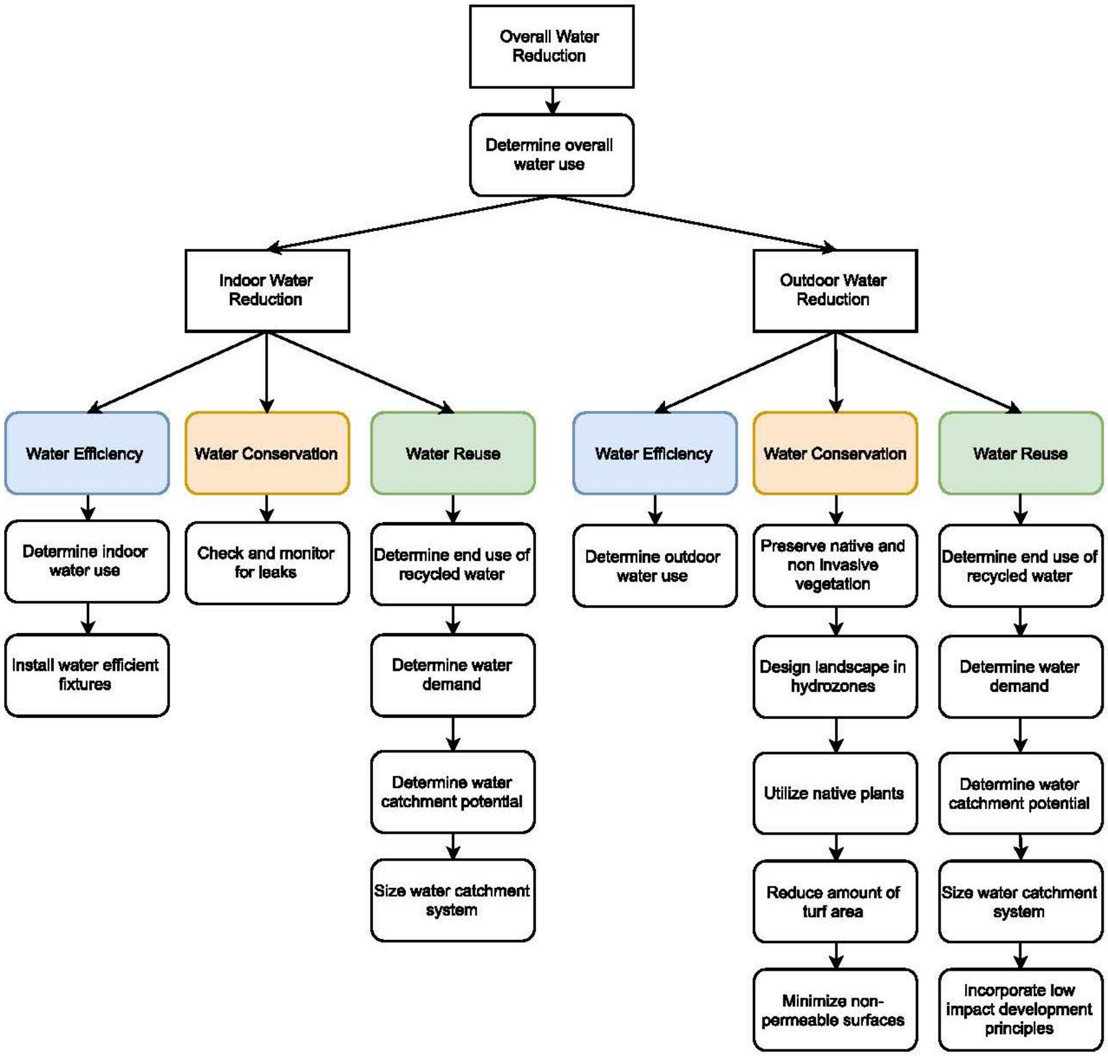

Figure 32: Design Guidelines Flowchart[200]

1. **Overall Water Reduction**

   <u>Objective</u>

   To reduce overall water consumption.

   <u>Requirements</u>

   Reduce overall water use by a minimum of 40% but should be reduced to the fullest extent possible.

   <u>Actions</u>

   1.1 Determine Overall Water use

[200] Made by Author.

1.2 Install sub meters to determine total water use, indoor water use and outdoor water use (sub meters can additionally be installed to determine water use for each type of fixture ex. toilets, faucets, irrigation, etc.). Meter data should be compiled into monthly and annual summaries.

2. Indoor Water Reduction

Water Efficiency -Determine indoor water use -Install water efficient fixtures
Water Conservation -Check and monitor for leaks
Water Reuse -Determine end use of water -Determine water demand -Determine catchment potential -Size catchment system

Objective

To reduce indoor water consumption.

Requirements

Reduce indoor water use by a minimum of 30% but should be reduced to the fullest extent possible. If using water reuse measures, reduce water use by a minimum of 45% to the fullest extent possible.

Actions

2.1 Indoor Water Efficiency

2.1.1 Determine indoor water use by fixture from sub meters

2.1.1.1 If sub meters are not installed, water use can be determined by a student count

2.1.1.2 Daily toilet usage can be found by adding daily women's toilet usage and the daily men's toilet usage. The daily toilet usage for the Women's toilet can be found by multiplying the number of women by four then multiply by the gallons per flush of the fixture. Toilet usage for men can be found by multiplying the number of males by the gallons per flush of the fixture. The women's and men's toilet usage should then be added to find the daily toilet usage.

Daily Women's Toilet Usage = (number of women x 4) x (gallons per flush)

Daily Men's Toilet Usage = number of men x gallons per flush

Daily toilet usage = (Daily Women's Toilet Usage) + (Daily Men's Toilet Usage)

2.1.1.3 The daily urinal usage can be found by multiplying the number of males by three then multiplying by the gallons per flush of the fixture.

Daily Urinal Usage = (number of boys x 3) x (gallons per flush)

2.1.1.4 The daily faucet usage can be found by multiplying the number of students by 0.25 (15 seconds) and then multiplying by the gallons per minute of the fixture.

Daily Faucet Usage = (number of students x 0.25 x gallons per minute)

2.1.1.5 All of the daily fixture usages should be added to find the total daily water usage (this example only includes toilets, urinals and faucets; additional fixtures should be considered and included).

Total Daily Indoor Usage = (daily toilet usage) + (daily urinal usage) + (daily faucet usage)

2.1.1.6 Annual usage is determined by adding the total usage for schooldays and the total usage for non-school days. Total usage for school days is found by multiplying the total daily indoor usage by 190. The total usage for non-school days is the total daily indoor usage multiplied by 175 and then multiplied by 5%

Total Indoor Usage (schooldays) = total daily indoor usage x 190

Total Indoor Usage (non-schooldays) = (total daily indoor usage x 175) x 5%

Total Annual Indoor Usage = (Total indoor usage (schooldays)) + (Total indoor usage (non-schooldays))

2.1.2 Install water efficient fixtures. For fixtures and fittings listed in **Error! Reference source not found.** as applicable to the project scope, reduce potable water consumption by 20% from the baseline.

Fixture or fitting	Amount of Water Consumed
Toilet	1.6
Urinal	1.0 gpf
Lavatory Faucet	0.5 gpf
Kitchen Faucet	2.2 gpm
Showerhead	2.5 gpm

Table 1: Baseline Water Consumption of Fixtures and Fittings[201]

A complete list of water efficient fixtures can be found at https://www3.epa.gov/watersense/product_search.html

2.1.2.1 Fixtures should be chosen upon project needs, users, etc.

2.1.3 Install appliances, equipment and processes within the project scope that meet the requirements listed in Table 2: Standards for ProcessesTable 2.

[201] "LEED | U.S. Green Building Council." LEED | U.S. Green Building Council. Accessed February 08, 2017. http://www.usgbc.org/leed.

Process	Requirement
Heat rejection and cooling	No once-through cooling with potable water for any equipment of appliances that reject heat
Cooling towers and evaporative condensers	Equip with: • Makeup water meters • Conductivity controllers and overflow alarms Efficient drift eliminators that reduce drift to maximum of 0.002% of recirculated water volume for counter flow towers and 0.005% of recirculated water flow for cross flow towers

Table 2: Standards for Processes[202]

2.2 Indoor Water Conservation

2.2.1 Determine indoor water consumption (See 2.1.1)

2.2.1.1 This can be found by checking billing statements to see how many gallons of water is used per month.

2.2.2 Check building and monitor for leaks in plumbing and fixtures

2.2.2.1 This can be done by shutting and turning off all fixtures and checking to see if the meter moves within a span of about 2-3 hours. If the meter moves, there is a leak and the building should be checked for leaks

2.2.3 Ensure faucets and fixtures are turned off when not being used

2.3 Indoor Water Reuse

2.3.1 Determine influent water type (storm water, greywater, black water)

2.3.1.1 Storm water requires the least filtration and treatment

2.3.1.2 Greywater can be used for irrigation but has guidelines that must be followed (refer to Chapter 5: Water Reuse)

2.3.1.3 Blackwater requires the most treatment when being used as it must be treated to rid water of bacteria and contaminants

2.3.2 Determine end use of recycled water (potable water vs. non-potable water)

2.3.2.1 Toilets and laundry use indoors can use non-potable water. Other uses will require potable water and require further treatment

2.3.2.2 Depending on influent water type, additional treatment may be necessary

2.3.3 Determine water demand for recycled water

2.3.3.1 Based on end use of recycled water, use monthly data to determine how much water is needed per month

2.3.4 Determine water catchment potential

[202] "LEED | U.S. Green Building Council." LEED | U.S. Green Building Council. Accessed February 08, 2017. http://www.usgbc.org/leed.

2.3.4.1 Water catchment potential can be found using the formula

Monthly Harvested Rainfall = (monthly rainfall x roof area x 0.623) x 2/3

2.3.5 Size water catchment system

2.3.5.1 Water catchment system should be based upon the monthly harvested rainfall and how much water is used per month. First flush devices and pumps should be considered when choosing a water catchment system.

3. Outdoor Water Use Reduction

Water Efficiency -Utilize smart water controllers
Water Conservation -Preserve native and non-invasive vegetation -Design landscape in hydro zones -Utilize native plants -Reduce amount of turf area -Minimize non-permeable surfaces
Water Reuse -Determine end use of water -Determine water demand -Determine catchment potential -Size catchment system -Incorporate low impact design principles

Objective

Reduce outdoor water consumption.

Requirement

Reduce outdoor water use by a minimum of 30% but should be reduced to the fullest extent possible. If using recycled water, reduce water use by a minimum of 45% to the fullest extent possible.

Actions

3.1 Outdoor Water Efficiency

3.1.1 Utilize smart water controllers and water saving irrigation components throughout site.

3.2 Outdoor Water Conservation

3.2.1 Determine outdoor water use

3.2.1.1 If sub meters are not installed, water use can be determined from monthly billing statements

3.2.1.2 Outdoor water use can be found by subtracting total indoor water use from the total overall water use.

3.2.2 Preserve native trees and noninvasive vegetation during development where feasible.

3.2.3 Design landscape in hydro zones or water use zones that have similar slope, sun exposure, soil conditions and plant materials with similar water needs.

3.2.3.1 Vegetation can usually be divided into three water zones: low (fed solely by rainfall), moderate (needs occasional watering), and high (requires regular watering)

3.2.4 Utilize native plants

3.2.4.1 Plants that can be used in Hawaii can be found in the Appendix.

3.2.5 Reduce amount of turf area to only functional areas. Turf area should only be used in areas being used for walking, sitting, and other recreational activities

3.2.5.1 If turf grass is to be used, zoysia el toro should be used as it has a good drought tolerance.

3.2.6 Non-permeable surfaces should be minimized and replaced with permeable surfaces where applicable

3.3 Outdoor Water Reuse

3.3.1 Determine influent water type (storm water, greywater, black water)

3.3.1.1 Storm water requires the least filtration and treatment

3.3.1.2 Greywater can be used for irrigation but has guidelines that must be followed (refer to Chapter 5: Water Reuse)

3.3.1.3 Blackwater requires the most treatment when being used as it must be treated to rid water of bacteria and contaminants

3.3.2 Determine end use of recycled water (potable water vs. non-potable water)

3.3.2.1 All irrigation can be fed with non-potable rainwater. If there are other outdoor uses, the end use water quality should be assessed.

3.3.2.2 Depending on influent water type, additional treatment may be necessary

3.3.3 Determine water demand for recycled water

3.3.4 Determine water catchment potential

3.3.4.1 Water catchment potential can be found using the formula

Monthly Harvested Rainfall = (monthly rainfall x roof area x 0.623) x 2/3

3.3.5 Size water catchment system

3.3.5.1 Water catchment system should be based upon the monthly harvested rainfall and how much water is used per month. First flush devices and pumps should be considered when choosing a water catchment system.

3.3.6 Incorporate low impact development principles where applicable

3.3.6.1 Bio retention basins can be placed in areas to slow and treat storm water runoff

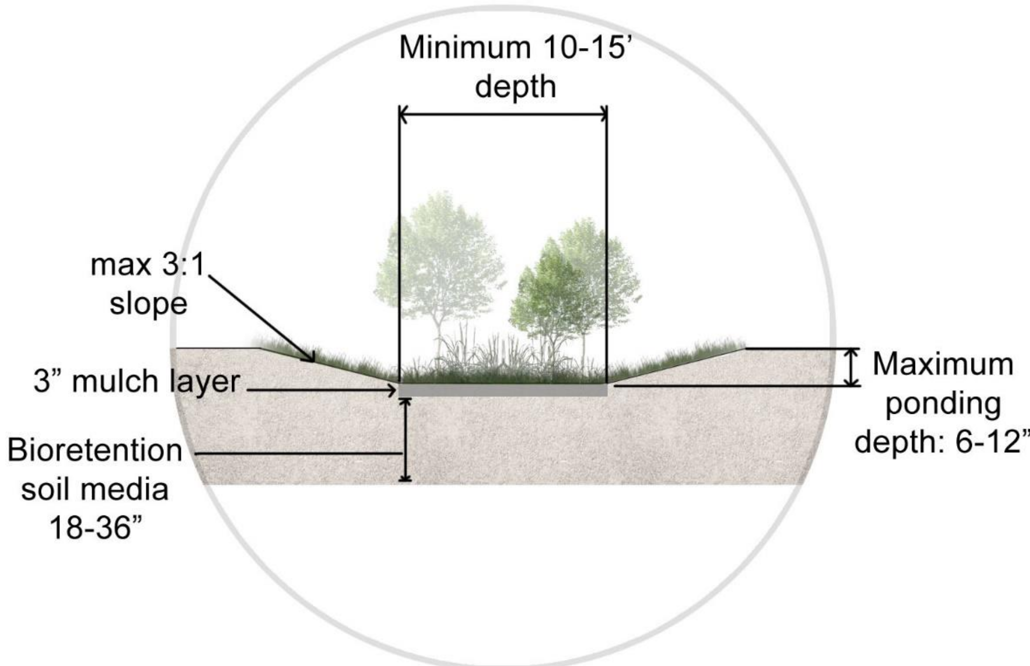

Figure 33: Bio retention Basin[203]

3.3.6.1.1 Bio retention basin should be 3-5% of the contributing drain area

3.3.6.1.2 Mulch layer should be about 3”

3.3.6.1.3 Filter media depth should be a minimum of 18 inches and maximum of 36 inches

3.3.6.1.4 Grass buffer strips should have a recommended max 3:1 slope

3.3.6.1.5 Maximum ponding depth 6 to 12 inches

3.3.6.1.6 Bio retention area should be a minimum of 10’-15’ in width

3.3.6.2 Rain gardens collect and slow storm water runoff and increases infiltration into the soil

3.3.6.2.1 Keep rain garden at least 10 feet away from the building

3.3.6.2.2 Rain gardens can typically be sized by estimating the amount of area that will drain into the garden then dividing that area by 6 for sandy soils and 3 for clayey soils. This calculation sizes the garden to hold one inch of runoff from the drainage area, in a garden 6 inches deep.

[203] Made by Author.

3.3.6.2.3 Underlying soils are an important component of the rain garden. Soils that infiltrate more slowly will require a larger rain garden.

3.3.6.3 Grass swales are lined with dense vegetation can treat, attenuation and convey excess runoff

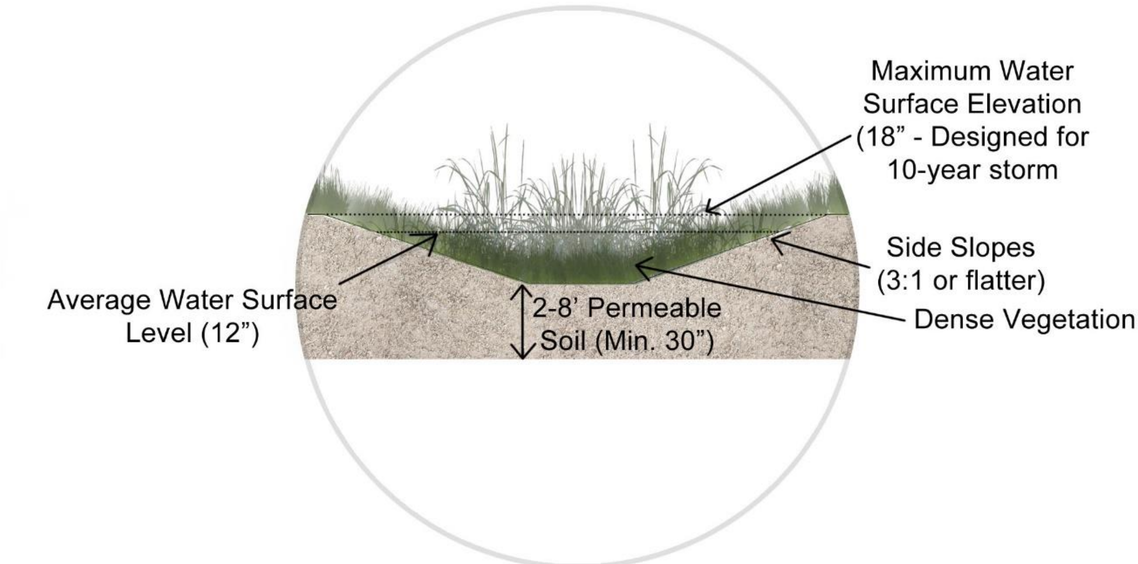

Figure 34: Grass Swale[204]

3.3.6.3.1 Plant dense, low growing native vegetation that is water resistant, drought and salt tolerant

3.3.6.3.2 Longitudinal slopes can range from 2%-6%[205]

3.3.6.3.3 Side slopes range from 3:1 to 4:1[206]

3.3.6.3.4 Bottom width of 2 to 8 feet

3.3.6.3.5 Swales should be designed to convey the peak flow of the 10-year storm without overtopping

3.3.6.4 Green roofs contain vegetation that can extend the life or the roof and reduce the volume and peak rates of storm water runoff

3.3.6.4.1 A green roof is a multilayered constructed material that consists of a vegetative layer, media, a geotextile layer and a synthetic drain layer

3.3.6.5 Permeable pavements reduce the amount of impervious areas and allow storm water to infiltrate into underlying soils

3.3.6.5.1 Permeable pavements should be located in low traffic areas such as sidewalks or parking areas

3.3.6.6 Constructed wetlands can remove sediments and other storm water pollutants to improve water quality

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[204] Made by Author.

[205] Pennsylvania Stormwater Management Manual. PDF.

[206] Pennsylvania Storm water Management Manual. PDF.

3.3.6.7 Disconnect downspouts from sewer connection

- 3.3.6.7.1 Downspouts should be diverted into a landscaped area such as a rain garden to allow water to infiltrate rather than going straight to the sewer
- 3.3.6.7.2 Downspouts can also be directed into rain barrels or into a water catchment system for water reuse

8. Case Studies

8.1 Introduction

This section features two case studies. Each of the case studies is an educational facility that displays and uses a number of water efficient strategies throughout the project. These case studies will be used to investigate what kind of strategies that can be used in the Hokulani project.

8.2 University of Hawaii Community College Palamanui Campus

8.2.1 Introduction

Figure 35: Palamanui Campus Map[207]

Hawaii Community College is a two-year community college that is located on Hawaii Island. The college is based in Hilo with a new campus branch in Kona named

[207] "About PALAMANUI." PALAMANUI. Accessed October 30, 2016. http://hawaii.hawaii.edu/palamanui/about/.

Hawaii Community College-Palamanui. Hawaii Community College Palamanui opened in Fall 2015.

Figure 36: Proposed Community Plan[208]

[208] Palamanui. "Hawaiʻi Community College Pālamanui Campus." Palamanui: HCC Pālamanui Campus. Accessed October 30, 2016. http://www.palamanui.com/cms/View.aspx/Show/HCCPalamanuiCampus.

The Palamanui campus was built on undeveloped virgin lava land in Kona near the Kona International Airport. Palamanui is off the grid in many ways including no sewer/wastewater utility line to the site.

Figure 37: Palamanui Campus[209]

8.2.2 Water Efficiency, Conservation and Reuse Strategies

Landscaping

The design intent of the Hawaii Community College Palamanui is to use zero potable water for landscape irrigation. This means that all water that is used for irrigation must come from storm water or recycled water. This goal is achieved by using strategies such as a drip irrigation system, drought tolerant and native plants and treating 100% of the wastewater on site for irrigation.

To reduce overall water consumption drought tolerant and low water demand local trees and plants such as monkey pod tree, hala, naupaka, ‘a’ali’i, buffel grass, maiapilo, pohinahina and ukiuki were selected.[210] Subsurface drip irrigation and subsurface bubbler were also used to reduce the amount of water being used for irrigation. The project also used weather and moisture sensor automatic irrigation controls to ensure the appropriate amount of water was being used when irrigating. In addition, mulch was used in all shrub areas to minimize evapotranspiration. The project also integrated low impact design strategies such as rain gardens and bio swales to take advantage of the infrequent seasonal rainfall.

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[209] Palamanui. "Hawaiʻi Community College Pālamanui Campus." Palamanui: HCC Pālamanui Campus. Accessed October 30, 2016. http://www.palamanui.com/cms/View.aspx/Show/HCCPalamanuiCampus.
[210] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.

The design team also implemented a temporary irrigation system. The proposed irrigation system was designed and built to use non-potable source water only and will not require any potable water for the permanent landscape irrigation system.[211] The supplemental temporary irrigation system will be provided via potable source water system for a one year establishment period. Within one year the temporary irrigation system will be removed.

Areas to be landscaped were separated into zones based on levels of priority. Each zone is planted in clusters using xeriscape planting. Soil, compost and mulch were used for landscaping and were all locally sourced and extracted from the state of Hawaii.[212] All plants that were used for the project are either Native Hawaiian or Polynesian plants that are commonly found in the native lowland, dryland and coastal areas of the island. This ensures that plants are accustomed to the climatic conditions of the project area. Plant selections were based on their drought tolerance, ecological value and aesthetics. Special efforts were also made to reuse on site lava rock materials as non-vegetated ground cover. This reduces the overall water requirements for landscape and reduces lifecycle maintenance.

The irrigation system for the landscape applies water using a combination of water efficient subsurface drip tubing and root zone water system with subsurface bubbler sprinkler. This system efficiently distributes the limited amount of non-potable source water that is generated for irrigation usage. The irrigation system also has an automatic controller that can be linked to local weather and moisture conditions through ET based weather sensors. This type of control allows for efficiently and timely application of water as needed by the planting. The time of day, length and frequency of water times are variables that can be programmed to achieve optimum use of the water that is designated for irrigation use.

The Palamanui project also features on site wastewater treatment. The wastewater that is produced by the Hawaii Community College Palamanui campus is managed on site with a natural wastewater treatment system. The treatment facility will produce tertiary treated (<10 mg/L BOD), <10 mg/L TSS) reclaimed effluent with significant nutrient removal suitable for onsite irrigation reuse.[213] The system is designed to meet 100% of the irrigation demand for landscape plantings at the site. Any excess effluent will be infiltrated. The treatment system uses primary treatment tanks, horizontal subsurface wetlands (HSSF), a recirculating sand filter and a subsurface drain field. Effluent that is destined for irrigation reuse is further filtered and disinfected prior to use. The system is simple and energy efficient because it utilizes natural treatment processes to produce reclaimed water that is suitable for irrigation and safe for infiltration. This system reduces the use of potable water as well as decreasing water and sewage costs.

[211] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[212] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[213] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.

The treatment system provides tertiary treatment that is suitable for subsurface irrigation for reuse for the University's landscape areas. It also provides nutrient reductions and provides habitats and beauty. The system relies on passive, natural technologies and is therefore energy efficient. The system can also be used for educational and outreach purposes. The system is also one that can be replicated and expanded if the campus decides that it wants to add more buildings. The proposed treatment system components include:

Primary treatment tanks (septic tanks & grease interceptor for the kitchen) at each building or group of buildings

Small diameter collection system from tanks to treatment site

Subsurface flow constructed wetlands

Recirculating sand filters

UV disinfection and final filtration (for reclaimed water only)

Step 1: Primary treatment tanks with effluent filters

The primary treatment tanks are located at each building or group of buildings. They have a total capacity of approximately 18,000-19,000 gallons which in means the system can handle up to 8,290 gpd of wastewater designed to meet Hawaii Department of Health Wastewater Branch (DOH) flow standards for the buildings' build out capacity. There are currently three septic tank zones for phase 1.[214] The first zone is located near the Culinary Arts Academy that will accommodate flows for the kitchen and restrooms. The kitchen wastewater will be treated in a grease interception that have a 1,250-gallon capacity before it moves into the septic tank. Zone 2 and 3 septic tank zones will be places next to the Phase 1B buildings which do not have a commercial kitchen.

Septic Tank Effluent Filters and Pump Systems

The elevation and distance prohibit the possibility of achieving gravity flow from septic tank zones to the HSSF wetland for secondary treatment. A septic tank effluent pump (STEP) system is installed in each of the three septic tank zones.[215] After solids settling in the primary septic tank chamber, a duplex ½ horse power pump system will be located in the secondary tank/chamber and effluent will be pumped through an effluent filter before moving into the collection system. The use of tanks with screens, with or without pumps, has been documented to reduce raw wastewater BOD5 by more 64% and total suspended solids by more than 90%.[216]

Step 2: Small Diameter Collection System

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[214] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[215] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[216] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.

The STEP system will connect into a singular small 2-inch diameter pipe collection system that will transport the water from the primary treatment tanks to the HSSF constructed wetland treatment system.[217] The small diameter collection systems are easier to be installed due to their smaller pipe size. They are also able to be buried at shallow depths below grade and require significantly less earthworks than conventional sewer systems. Shoring of trenches is not necessary because the small diameter sewer line is generally set at 24 to 60 inches below grade and follows the profile of the road.

Step 3: Horizontal Subsurface Flow Constructed Wetland

Natural wetlands serve as the liver and kidneys of the earth by filtering and assimilating nutrients from water. Wetlands are commonly found bordering coastal and terrestrial environments. Sediments settle out from rivers and streams and nutrients are assimilated before the water enters the sea in wetlands. These environments that act as a sponge are critical for decomposing and transforming debris into food and habitat for the coastal ecosystem.

Unlike natural wetlands, constructed wetlands are not confined by the availability and proximity of water. Constructed wetlands mimic the natural 'composting' ability of natural wetlands by transforming 'pollution' into food for the wetland organisms. Constructed wetlands have become a popular option for wastewater treatment as an alternative to conventional wastewater treatment methods. Constructed wetlands applications can be extended to treat various types of wastewater such as domestic wastewater, industrial wastewater, agricultural wastewater, lake/river water, sludge effluent, storm water runoff, and agricultural runoff. Wetland plants can help clean water in a wetland as they filter water as it enters the wetland and helps to draw out chemicals. Many plants absorb acid and keep the water safe for wetland inhabitants.

Constructed wetlands for wastewater treatment are designed to be mechanically simply yet ecologically complex. The secondary treatment technology follows primary treatment in a septic tank and replaces the need for a leach field. Constructed wetlands are passive, lined, ecological fixed film reactors that provide high quality secondary treatment that does not require external energy for treatment. Constructed wetlands can serve as an aesthetic addition to the landscape and a learning resource. In subsurface flow wetlands, all water flows below the surface and the plant roots and rock material provide substrates for microorganism attachment and habitat for the food web to be initiated. The two media provide different habitats that allow for both aerobic and anoxic bacteria to reside in the same ecosystem which allows for an efficient breakdown of a range of pollutants and removal of nutrients, converting these wastes into resources. Furthermore, the wetland treatment system can showcase native Hawaiian plants that promote the local culture and regional biodiversity.

[217] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.

The collection system delivers the primary treated effluent from the septic tanks to the HSSF constructed wetland for secondary treatment.[218] Subsurface horizontal flow constructed wetlands are lined gravel filters planted with wetland plant species. Two parallel cells of HSSF constructed wetlands each 2268 sq. ft. will be located in one area to manage flows from Phase 1 and later build out. The two, 36' x 63' cells will be operated in parallel, which means that each cell can process 50% of the overall flow, which provides great operational flexibility for periods of maintenance or in the event that repairs are needed.[219] A flow splitter will provide passive, gravity-driven flow splitting between the two cells. Each cell is outfitted with a 'level adjust sump' to control the water level in the wetlands to remain below the surface.

Influent enters through a buried infiltrator at the head of each wetland cell. Water moves horizontally subsurface through the gravel media and plant roots in the wetlands. All the effluent is maintained between 4" and 6" below the surface to eliminate odors and mosquitoes, and to minimize contact with wastewater effluent.[220] An HDPE (high density polyethylene) or PPE (polypropylene) liner will be used to provide a water-tight cell. Each cell has a freeboard (space above the gravel) of at least 12". All storm water from surrounding areas will be diverted away from the constructed wetlands cells. As water moves through the gravel and plant roots, attached growth bacteria and fungi (biofilms) breakdown and/or remove BOD, suspended solids, and nitrogen. The wetlands will be planted with native Hawaiian wetlands species to demonstrate a 'Hawaiian' garden and create habitat.

Step 5: Mechanical Filtration & Ultraviolet Disinfection

The irrigation reuse design flow is approximately 1,400 gpd and is first filtered and disinfected before being delivered to the irrigation storage and pressurization system. The filtration process is designed to remove remaining solids that might affect disinfection or clog the drip irrigation systems. This makes the UV disinfection process more effective since it reduces 'shading' by particles in the effluent stream. A 100 micron and 50 micro filter are used prior to disinfection through the ultraviolet disinfection unit (UV).[221]

UV disinfection systems use ultraviolet light to destroy bacteria and viruses. The treated effluent is pumped through the UV disinfection system at a fixed rate. Uniform flow through the UV unit allows for a predictable level of disinfection. The UV disinfection light destroys fecal coliform bacteria and other pathogens as the water flows along the length of the UV light tube. The light intensity and disinfection rate is affected by clarity of water and quality of suspended solids in the water column. Filtration using mechanical filters is essential for good performance. Removal of remaining suspended

[218] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[219] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[220] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[221] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.

solids ensures that almost all remaining fecal coliform bacteria are destroyed. Typical removal rates are 99.99%.[222]

Step 6: On Site Reuse:

The treatment system is designed to produce DOH R-3 quality effluent for drip irrigation. 100% of the landscape water demand for the Phase 1 buildings will be supplied by reclaimed water from the natural treatment system. The entire wastewater treatment system meets tertiary standards by limiting effluent in the reuse water to less than 10 mg/L BOD5 and 10 mg/L TSS.[223]

WATER SUBMETERING

Wastewater flows will be measured in three distinct locations: First the influent flow will be measured at the flow splitter just before the two wetland cells. This will help the operator to make adjustments to split the flow evenly between the two wetland cells as well as calculate total flow. The second meter will measure the total 'Effluent' coming out of the treatment system that flows into the drain field, located just after the Recirculating Sand Filter. Lastly the third flow meter will monitor the flow to the irrigation system. Water flows will be tracked with an online Building Dashboard interface as part of the "Building as an Educational Tool" program that the University will adopt.

Water Use Reduction:[224]

Dual flush water closets:	1.6/1.1 GPF
Ultra-low flow Urinal:	0.1 GPF
Low-flow Lavatory:	0.5 GPF
Low-flow Shower:	1.5 GPF
Low-Flow Kitchen Sink:	1.5 GPF

Baseline Case – Annual Water Consumption:	167,972 gallons/year
HawCC Palamanui – Annual Water Consumption:	90,128 gallons/year
Total Water Savings:	46.3 %

[222] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[223] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.
[224] Lee, Karen. "UH-HCC Palamanui." E-mail. October 21, 2016.

8.2.3 Conclusion

The Palamanui campus uses a variety of water efficiency, conservation and reuse strategies throughout the campus. The campus reduced water by utilizing water efficient fixtures such as dual flush toilets, ultra-low flow urinals and low flow showers. The reduction for the landscape water use is a large step in reducing the amount of water used. Using zero potable water for irrigation by using strategies such as drip irrigation, drought tolerant and native plants, and using wastewater treated onsite reduces a large amount of water since most water use is dedicated to irrigation.

The wastewater treatment system on site is also another strategy that reduces water use. The system includes horizontal subsurface wetlands to treat wastewater that is produced on campus. This water is then able to be reused for irrigation. Since the wetland is subsurface it is does not have water flowing above the surface. This is safer for users but does not allow people to fully ‘see’ the process that is taking place. Allowing the students to better understand and learn about all the systems would be a great educational tool that could be used on the campus.

8.3 Hawaii Preparatory Academy Energy Laboratory

8.3.1 Introduction

Figure 38: Hawaii Preparatory Academy Energy Laboratory[225]

Hawaii Preparatory Academy Energy Laboratory was designed by Flansburgh Architects and is in Kamuela, Hawaii. The building is a high school science building that

[225] "Hawaii Preparatory Academy Energy Lab." International Living Future Institute. Accessed October 29, 2016. http://living-future.org/case-study/hpaenergylab.

is dedicated to the study of alternative energy. It functions as a zero-net energy building that is fully sustainable.

The design of the energy lab was driven by two green building certification standards: LEED (Leadership in Energy and Environmental Design) and the Living Building Challenge. LEED certification exists at several levels: platinum, gold and silver. The Living Building Challenge is a more rigorous pass/fail certification, extending the challenge of LEED to include materials sourcing, one year post occupancy auditing and other criteria.[226] A building is judged on 7 "petals": site, water, energy, health, materials, equity, and beauty. The Energy Lab is the third project in the world to meet the Living Building Challenge standard. The project was completed in January 2010 and strives to become a functioning example of sustainability.[227]

The Energy Lab is situated at the north end of the HPA campus bordering the woods that surround the dorms and has excellent exposure to wind and solar energy as well as inspiring views.[228] The Energy Lab was designed around the science curriculum that it houses. The building features small project rooms, a large research center, and a laboratory. These spaces are designed to encourage student discovery, exploration and experimentation.[229] The Energy Lab's spaces flow into each other and are separated only by glass. This allows for fluid learning that breaks the industrial educational mold. The building links interior and outdoor spaces to facilitate scientific study indoors and out. One of the project's main goals is to educate the next generation of students in the understanding of environmentally conscious, sustainable living systems.

8.3.2 Water Efficiency, Conservation, and Reuse Strategies

The building generates all of its power from photovoltaic and windmill sources. The building currently only uses eight percent of the energy that it produces and the rest is net-metered back into the campus grid. The building also captures and filters all of its own drinking and wastewater as well as generating hot water from solar thermal panels.[230] The building also features natural ventilation and uses experimental radiant cooling systems as an alternative to air conditioning. All of these systems allow students to actively learn and engage with the built environment around them.

[226] "Hawaii Preparatory Academy - The Place." Hawaii Preparatory Academy. Accessed November 20, 2016. https://www.hpa.edu/academics/energylab/the-place.
[227] "Hawaii Preparatory Academy Energy Lab." International Living Future Institute. Accessed October 29, 2016. http://living-future.org/case-study/hpaenergylab.
[228] "Hawaii Preparatory Academy - The Place." Hawaii Preparatory Academy. Accessed November 20, 2016. https://www.hpa.edu/academics/energylab/the-place.
[229] "Hawaii Preparatory Academy Energy Lab." International Living Future Institute. Accessed October 29, 2016. http://living-future.org/case-study/hpaenergylab.
[230] "Hawaii Preparatory Academy Energy Laboratory / Flansburgh Architects." ArchDaily. 2010. Accessed October 29, 2016. http://www.archdaily.com/64732/hawaii-preparatory-academy-energy-laboratory-flansburgh-architects/.

Figure 39: Diagram of Systems[231]

The building has an experimental radiant cooling system as an alternative to conventional air conditioning. At night, water is circulated through thermal roof panels and cooled via lower evening temperatures. The water is then stored in a below grade tank to be used as chilled water for air handling units during the warm afternoons.[232]

Since the building is located at the windward edge of the campus it is able to take advantage of the trade winds that come down from the mountains above. The site faces the Mauna Kea volcano and many of the interior views are directed towards the volcano and the valley below. The southern exposure allows the building to optimize solar thermal and photovoltaic panel performance. The building also takes advantage of the Hawaiian climate by connecting the indoors and outdoors with operable glass doors. In response to the hillside topography of the site, the building's internal spaces where storage tanks, solar panels and other systems are housed, are stepped and terraced to take advantage of the change in elevation.[233]

The Elab online is that facility's website that tracks local weather data from multiple remote stations, monitors building systems and energy use, studies water consumption and rain collection and offers microclimate and building data to neighboring residents of Kamuela.[234] The Energy Lab's conference room has been designed to take advantage of Hawaii's bridge between the West Coast and Asian Mainland time zones.

[231] "Hawaii Preparatory Academy Energy Lab." International Living Future Institute. Accessed October 29, 2016. http://living-future.org/case-study/hpaenergylab.
[232] "Hawaii Preparatory Academy Energy Lab." International Living Future Institute. Accessed October 29, 2016. http://living-future.org/case-study/hpaenergylab.
[233] "Hawaii Preparatory Academy Energy Laboratory / Flansburgh Architects." ArchDaily. 2010. Accessed October 29, 2016. http://www.archdaily.com/64732/hawaii-preparatory-academy-energy-laboratory-flansburgh-architects/.
[234] "Hawaii Preparatory Academy Energy Laboratory / Flansburgh Architects." ArchDaily. 2010. Accessed October 29, 2016. http://www.archdaily.com/64732/hawaii-preparatory-academy-energy-laboratory-flansburgh-architects/.

Hawaii prep students are able to engage with both sides of the pacific during the regular school day via video conferencing.

Figure 40: Systems Diagram[235]

The Energy Lab also regulates its cooling/heating, watering and energy generation via input from over 250 sensors.[236] The Energy Lab self regulates the interior climate, maintaining temperature, relative humidity, and carbon dioxide levels in all the spaces at all times. The system optimizes building performance and ensures user's comfort.

An individual wastewater system provides treatment for domestic wastewater and on site infiltration. The proposed leaching field infiltration system disperses the treated wastewater over a larger area and allows the water to infiltrate back into the aquifers. This also facilitates an additional degree of treatment from soil biota and filtration as the water percolates through deeper soils before recharging the groundwater below. The energy lab also includes a 10,000-gallon water storage tank.[237] The water from this tank

[235] "Hawaii Preparatory Academy Energy Laboratory / Flansburgh Architects." ArchDaily. 2010. Accessed October 29, 2016. http://www.archdaily.com/64732/hawaii-preparatory-academy-energy-laboratory-flansburgh-architects/.
[236] "Hawaii Preparatory Academy Energy Laboratory / Flansburgh Architects." ArchDaily. 2010. Accessed October 29, 2016. http://www.archdaily.com/64732/hawaii-preparatory-academy-energy-laboratory-flansburgh-architects/.
[237] "Hawaii Preparatory Academy Energy Laboratory / Flansburgh Architects." ArchDaily. 2010. Accessed October 29, 2016. http://www.archdaily.com/64732/hawaii-preparatory-academy-energy-laboratory-flansburgh-architects/.

is filtered for potable drinking water as well as being used for waste systems. Water demand is also reduced by using low volume sink and toilet fixtures.

The Energy Lab has 6,100 square feet of roof area that is used to harvest both rainwater and condensation. The gutters direct the harvested water to a 10,000-gallon cistern that is located below the west veranda for storage before treatment.[238]

8.3.3 Conclusion

The Energy Lab at Hawaii Preparatory Academy uses a number of water efficiency, reuse and conservation strategies such as filtering all of its own drinking water and monitoring all of the building systems. The on-site wastewater system is not something that many facilities have and the large amount of rainwater that is collected is a great way to reduce the amount of potable water that is used. The Energy Lab also regulates its own cooling/heating, watering and energy generation with input from sensors. This self regulates the interior spaces and reduces overuse of heating and cooling systems. This is a great response to the climate of Hawaii.

The Elab online which tracks local weather data from multiple remote stations, monitors building systems and energy use, studies water consumption and rain collection and offers microclimate and building data to neighboring residents of Kamuela is a great way to get the community involved. This also helps students to better understand the climate and how the building must adjust to climate changes. This is a great learning tool that students can learn from.

[238] "Hawaii Preparatory Academy Energy Laboratory / Flansburgh Architects." ArchDaily. 2010. Accessed October 29, 2016. http://www.archdaily.com/64732/hawaii-preparatory-academy-energy-laboratory-flansburgh-architects/.

9. Design Proposal for Hokulani Elementary School

9.1 Introduction

Hokulani is an elementary that serves grades K-5. Hokulani is a public school located in Manoa near the University of Hawaii at Manoa Campus. Until the 1950's, children living in the present Hokulani School district attended Kuhio, Ali'iolani or Palolo Elementary Schools.[239] However, their parents longed to have a local school built, so residents and community leaders congregated to initiate the process.

On January 24, 1957, at a public hearing, it was proposed that 31,000 square feet of land that was allocated for the expansion of Kanewai Park be given to the Department of Education for a new school site.[240] The Tom family, who still resides in the area, also gave a pie-shaped piece of land which made it possible to create an entrance to the school from Kamakini Street.

In 1958, Hokulani opened with five grade levels, eight teachers and the principal. The office and health room were in A-1 and A-3 housed the library. There were only two buildings (Building A and B) when the school opened.

In 1960, Building C was completed. This was followed by the Multi-Purpose Building which was finally built in 1964 after several delays. The present Administration Building was completed in 1967 and in 1971 the Music Building that is now used for the computer lab was constructed, thus completing the physical layout of the school.[241]

Today, there are close to 400 students enrolled at Hokulani. Although the diverse student body is comprised primarily of our local children, they also serve a small percentage of students who are recent immigrants. For the most part, these are students whose parents are scholars from other countries and who live in nearby UH Manoa faculty housing. The remainder are students from the Orient, whose parents are currently working in the United States.[242]

History of Hokulani

Kanewai, where Hokulani is located, is an area where Manoa Stream emerges from the valley and opens to the broader expanse of the Waikiki floodplain. Manoa Valley receives a large amount of rainfall and has therefore resulted in an endless flow of

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[239] "Hokulani Elementary." Hokulani History – About Us – Hokulani Elementary. Accessed January 31, 2017. http://www.hokulani-elementary.com/apps/pages/index.jsp?uREC_ID=350591&type=d&pREC_ID=760729.

[240] "Hokulani Elementary." Hokulani History – About Us – Hokulani Elementary. Accessed January 31, 2017. http://www.hokulani-elementary.com/apps/pages/index.jsp?uREC_ID=350591&type=d&pREC_ID=760729.

[241] "Hokulani Elementary." Hokulani History – About Us – Hokulani Elementary. Accessed January 31, 2017. http://www.hokulani-elementary.com/apps/pages/index.jsp?uREC_ID=350591&type=d&pREC_ID=760729.

[242] "Hokulani Elementary." Hokulani History – About Us – Hokulani Elementary. Accessed January 31, 2017. http://www.hokulani-elementary.com/apps/pages/index.jsp?uREC_ID=350591&type=d&pREC_ID=760729.

water that was able to support irrigated agriculture downstream. An auwai, which is an irrigation ditch, was dug at Kanewai that diverts water from the stream to nearby pond fields.

Historical documents indicate that Kanewai was historically used primarily for agriculture production since the 15th century. Chief Kalamakua constructed numerous pond fields from the uplands to the sea during that time.

In 1783, Kahekili, Maui chief, took control of Oahu but two years later Kamehameha I conquered Oahu in the Battle of Nu‘uanu Pali. He then allocated his lands to favored warrior chiefs and counselors.

Most of the Ahupua‘a of Manoa was awarded to Ke’eamoku, his father in law. Ke’eaumoku assigned the ‘ili of Kanewai to a konohiki, a lesser chief and land manager, named Kaleiheana. When Ke’eaumoku died in 1804, his land was transferred to his daughter, Ka'ahumanu but in 1832, Ka'ahumanu passed away and her land was inherited by her daughter, Kïna'u. Upon Kïna’u’s death in 1839, her land, including the 'ili of Kanewai, went to her daughter, Victoria Kamamalu. During this period when the land was transferred from family member to family member, Kaleiheana remained as konohiki.

The Mahele of 1848 changed the Hawaiian land system from use rights to a system that was based on private ownership. The ‘ili of Kanewai remained in the royal family. The lands of Kanewai were primarily used for taro cultivation.

During the early part of the 20th century, the tradition of irrigated cultivation that the Hawaiians began centuries earlier, continued. Kwong Yik Farms leased the Kanewai area from Bishop Estate and employed bachelor farmers from China who created a lush, thriving landscape of terraced vegetable gardens and lotus ponds, which extended all the way down to Old Wai'alae Road. Mustard cabbage, white cabbage, green onions, spinach, Chinese parsley and lotus root among many other vegetables grew abundantly in the rich soil.

An auwai was constructed to divert water from Manoa Stream to the fields. It originated near the East-West Center, flowed along the base of Waahila, ran down into Kanewai and back to the stream. The farmers constructed numerous waterways throughout the fields to bring the life-giving water to their crops. Medaka, catfish, rainbow fish, small shrimp, pipipi, dojo and opae thrived in these ditches and provided endless hours of fun for neighborhood children who enjoyed catching them until the farmers got annoyed.

9.2 Site Analysis

Hokulani Elementary School is located in Honolulu, Hawaii between the University of Hawaii at Manoa and Chaminade University.

Figure 41: Hokulani Elementary School Context Map[243]

Figure 42: Hokulani Elementary School Map[244]

The area surrounding Hokulani receives a mean annual rainfall of 34.47 inches (875.5 mm).[245]

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[243] "Google Maps." Google Maps. Accessed February 16, 2017. https://www.google.com/maps/place/Hokulani Elementary School
[244] Made by Author.
[245] Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013: Online Rainfall Atlas of Hawaiʻi. Bull. Amer. Meteor. Soc. 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1.

Figure 43: Mean Monthly Rainfall Near Hokulani Campus[246]

[246] Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013: Online Rainfall Atlas of Hawai'i. Bull. Amer. Meteor. Soc. 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1.

Figure 44: Rainfall Data Near Palamanui Campus[247]

[247] Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013: Online Rainfall Atlas of Hawai'i. Bull. Amer. Meteor. Soc. 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1.

Hokulani falls in the Ala Wai watershed. A watershed is the area of land where the water that falls in it and drains off it goes to a common outlet.[248] Hokulani School falls in the Ala Wai watershed. The Hawaiian meaning of the name is "freshwater way". The watershed is 19 square miles with a maximum elevation of 3,051 ft. [249] The Ala Wai watershed extends from the ridge of the Ko'olau Mountains to the waters of Mamala Bay including Makiki, Manoa, and Palolo streams. These streams drain into the Ala Wai Canal which is a 2-mile-long, man-made waterway that was constructed during the 1920s to drain extensive coastal wetlands.

[248] Perlman, Howard. "What is a watershed?" Watersheds and drainage basins, USGS Water Science School. Accessed January 15, 2017. https://water.usgs.gov/edu/watershed.html.
[249] Parham, James E. Atlas of Hawaiian watersheds & their aquatic resources. Honolulu: State of Hawaiʻi, Department of Land & Natural Resources, Division of Aquatic Resources, 2008.

Figure 45: Ala Wai Watershed[250]

The campus sits on approximately 8 acres of land. Hokulani consists of 6 main buildings that includes 3 classroom buildings (Building A, Building B, and Building C), a multipurpose room/cafeteria space, library/computer lab and an administration building.

[250] Parham, James E. Atlas of Hawaiian watersheds & their aquatic resources. Honolulu: State of Hawaiʻi, Department of Land & Natural Resources, Division of Aquatic Resources, 2008.

Figure 46: Hokulani Elementary School Buildings[251]

Building A is a one-story building that houses 4 classrooms and one kitchen space. One classroom is used an art room and the other 3 are used for classes. For the calculations within this paper, there are three classrooms with 24 students each. All classrooms should be calculated with before and after school activities from 7 am to 4 pm. There are also 3 boy's restrooms and 3 girl's restrooms with two toilets each.

Building B is a two-story building that houses eight classrooms. For the calculations within this paper, there are eight (8) classrooms with 24 students each. All classrooms should be calculated with before and after school activities from 7am to 4pm. There is also one girl's restroom (with 5 toilets), one boy's restroom (with 4 toilets) and a small adult unisex restroom on each floor.

Building C is a two-story building that house eight classrooms. One classroom is used as an art/activity room. The other seven are scheduled for classes. For the calculations within this paper, there are seven (7) classrooms with 24 students each. All classrooms should be calculated with before and after school activities from 7am to 4pm. There is also one girl's restroom (with 3 toilets,1 shower, and 2 sinks), one boy's restroom (with 3 toilets, 3 urinals and 2 sinks) and a small adult unisex restroom on each floor.

The multipurpose room (Building D) is a one-story building that serves as a multipurpose room as well as a cafeteria. The building also has one girl's and one boy's toilet.

The library building (Building G) is a one-story building. There are no restrooms in Building G.

[251] Made by Author.

The administration building is a two-story building that houses offices, a teacher's lounge, conference room, storage, and a reading room. There is also one men's, one women's and a unisex restroom within the building.

The campus buildings are not sub metered for water; therefore, the loads were disaggregated from site observations.

9.3 Existing Water Efficiency Guidelines

The guidelines were developed by looking at HI CHPS program, LEED, the Living Building Challenge and Ka Hei. The CHPS is a national movement to improve student performance and the entire educational experience by building the best possible schools. HI CHPS is criteria specifically for Hawaii and is designed to help school districts reduce operating costs, achieve higher student performance, increase daily attendance, retain quality teachers and staff and minimize environmental impact.[252] LEED or Leadership in Energy and Environmental Design is a green building certification program that was developed by the U.S. Green Building council that includes a set of rating systems for the design, construction, operation and maintenance of green buildings, homes and neighborhoods. This program aims to helping owners be environmentally responsible and use resources efficiently.[253] The Living Building Challenge is one of the most rigorous performance standards for buildings. The Living Building Challenge seeks to design buildings that like a flower, give more than they take.[254] Ka Hei is a 5-year program that was launched in 2014 by the Department of Education to integrate energy technology with meaningful learning experiences all while reducing energy costs.[255]

9.3.1 HI CHPS

HI CHPS has a number of requirements that are placed in different categories including: outdoor water budget and irrigation system performance, minimum reduction in indoor potable water use, indoor water use reduction, reduce potable water use for sewage conveyance, reduce potable water use for non-recreational landscaping areas, reduce potable water use for recreation landscaping areas, irrigation system commissioning, and water management system. Each of these sections offers points based on how much water reduction is achieved.

9.3.2 LEED

LEED is similar to HI CHPS in that the water efficiency portion is separated into sections. These sections include prerequisites which are outdoor water use reduction, indoor water use reduction, and building-level water metering and sections for credits which are outdoor water use reduction, indoor water use reduction, cooling tower water use, and water metering. Each of these sections have a number of points that can be rewarded based on meeting different standards.

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[252] "The CHPS Criteria." The CHPS Criteria | CHPS.net. Accessed February 08, 2017. http://www.chps.net/dev/Drupal/node/212.
[253] "LEED | U.S. Green Building Council." LEED | U.S. Green Building Council. Accessed February 08, 2017. http://www.usgbc.org/leed.
[254] "Living Building Challenge." The Living Future Institute. Accessed February 08, 2017. https://living-future.org/lbc/.
[255] "Hawaii DOE | Ka Hei." Hawaii DOE | Ka Hei. Accessed February 08, 2017. http://www.hawaiipublicschools.org/ConnectWithUs/Organization/SchoolFacilities/Pages/Ka-Hei.aspx#update.

9.3.3 Living Building Challenge

The objectives of both the Living Building Challenge and Ka Hei are the least descriptive. The goals of the Living Building Challenge are the most rigorous as it requires 100% of the project's water needs to be supplied by captured precipitation or other natural closed loop water systems and/or by recycling used project water and must be purified as needed without the use of chemicals. In addition, all storm water and water discharge including grey and black water must be treated onsite and managed either through reuse, a closed loop system or infiltration.

9.3.4 Ka Hei

Ka Hei is a Department of Education program that integrates energy technology with learning experiences. Ka Hei mainly focuses on reducing energy costs but also includes sustainability objectives. Ka Hei focuses on increasing sustainable practices as well as encouraging students learning and engaging educational opportunities. The goal of Ka Hei is the least specific with the key objective in water use being a 30 percent reduction in water consumption over five years.

9.4 Water Use Reduction Guidelines for Schools

9.4.1 Indoor Water Use Reduction

Using Hokulani's water use as a case study, we can see how much water a school of about 400 students uses. By looking at the number of students and the standard fixtures that are used, school can reduce their indoor water use by at least 30% by incorporating water efficient fixtures. In addition, by using this data as well as seeing how much surface area can be conservatively used for water catchment, it is reasonable to say that schools of the same size, with the same number of students can save an additional 15% of water by supplementing their potable water with recycled water. By looking at the precipitation maps of the island of Oahu we can see that the West side receive the least amount of rain (about 20 in) annually. These schools can reduce their potable water usage by about 142,501 gallons. Schools can reduce their water use by supplementing their potable water with recycled water.

9.4.2 Outdoor Water Use Reduction

Reduce or eliminate potable water use for landscape irrigation for non-recreational areas. Potable water use should be reduced by 30%. Potable water, natural surface water or groundwater consumption for irrigation of non-recreational landscape areas can be reduced by using water efficient native or adapted climate tolerant plantings, high efficiency irrigation controllers, soil moisture meters/rainfall sensors or using captured rain or reclaimed water.

9.4.3 Water Metering

Permanent water meter should be installed to measure the total potable water use for the building and associated grounds. Meter data must be compiled into monthly and annual summaries; meter readings can be manual or automated. This will allow users to understand how water is being used. This will also help users to monitor for leaks or system losses.

9.5 Hokulani Water Use

Hokulani's total water use is shown below. The data was averaged over a 3-year span. From the data, we can see that water use decreased during the winter and summer months since the students are on break. The school does not have sub meters so the data for fixture use and irrigation needed to be disaggregated by site studies.

	2013 (gallons)	2014 (gallons)	2015 (gallons)	Average (gallons)
January		44	53	32.33
February	54.074	63	77	64.69
March	20.483	72	75	55.83
April	135.517	82	92	103.17
May	87	88	102	92.33
June	93	62	89	81.33
July	38	32	101	57
August	67	58	85	70
September	83	123	70	92
October	88	116	45	83
November	108	80	73	87
December	77	78	53	69.33

Table 3: Hokulani Elementary School Average Water Use[256]

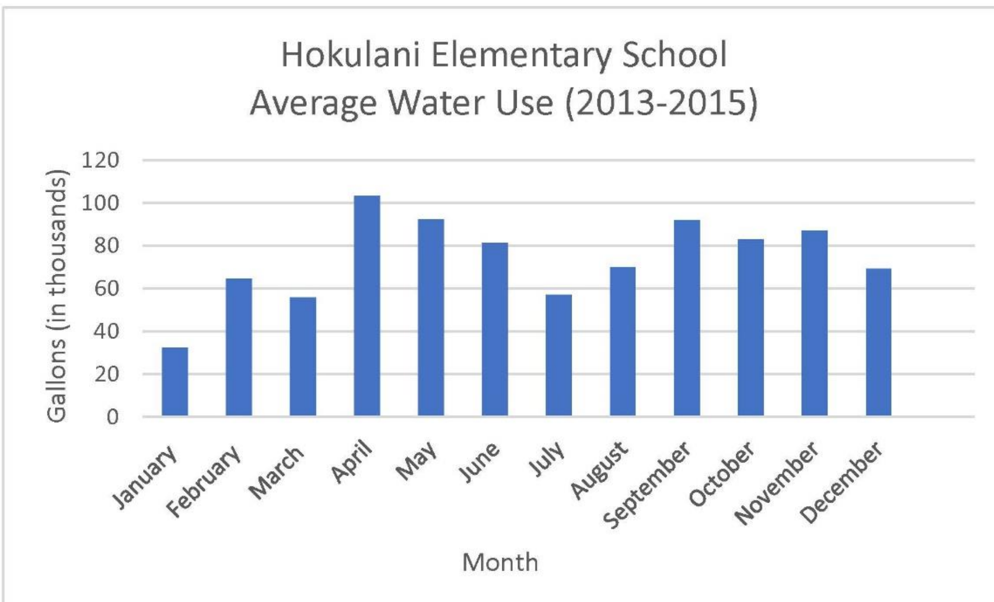


Figure 47: Hokulani Elementary School Average Water Use (2013-2015)[257]

Hokulani's water data was then separated by different uses. Site studies were performed to account for all fixtures in the buildings. Flow rates on all fixtures were measured and this information was then used to calculate annual water use for each fixture. The following assumptions were made:

- Based on the number of classrooms Building A contained: 72 students; 50/50 boy/girl; 6 Adults
- Based on the number of classrooms, Building B contained: 96 students upstairs/84 students downstairs; 50/50 boy/girl; 16 adults; 8 per floor

[256] Made by Author.
[257] Made by Author.

- Based on the number of classrooms, Buildings C contained: 84 students upstairs/84 students downstairs; 50/50 boy/girl; 12 adults; 6 per floor
- Based on the number of classrooms, Building D contained: 24 students; 50/50 boy/girl; 4 adults
- Administration Building: 10 adults first floor; 4 adults second floor
- Each girl: 4 toilet flushes per day
- Each boy: 3 urinal flushes per day; 1 toilet flush per day
- Standard showerhead 2.5 gpm
- WaterSense showerhead 2.0 gpm
- Standard bathroom faucet 2.2 gpm
- WaterSense faucet no more than 1.4 gpm
- 190 school days, 175 off days use 5% of school days
- Wash hands: 15 seconds

Type	Location	Building	Description	G/use	Uses/day	Units	total G/d	Total g/yr Schooldays	Non-Schooldays at 5%	Total Water Use
Toilet	1st Floor	Building A	Standard inefficient units 3.0 gal/flush, pressurized	1.6	144	12	230.4	43776	2016	
	Girls 1st Floor	Building B	Standard inefficient units 3.0 gal/flush, pressurized	1.6	192	5	307.2	58368	2688	
	Boys 1st Floor	Building B	Standard inefficient units 3.0 gal/flush, pressurized	1.6	48	4	76.8	14592	672	
	Adult 1st Floor	Building B	Standard inefficient units 3.0 gal/flush, pressurized	3	32	1	96	18240	840	
	Girls 2nd Floor	Building B	Standard inefficient units 3.0 gal/flush, pressurized	1.6	192	5	307.2	58368	2688	
	Boys 2nd Floor	Building B	Standard inefficient units 3.0 gal/flush, pressurized	1.6	48	4	76.8	14592	672	
	Adult 2nd Floor	Building B	Standard inefficient units 3.0 gal/flush, pressurized	3	32	1	96	18240	840	
	Girls 1st Floor	Building C	Water efficient unit 1.28 gal/flush	1.28	168	3	215.04	40857.6	1881.6	
	Boys 1st Floor	Building C	Water efficient unit 1.28 gal/flush	1.28	42	3	53.76	10214.4	470.4	
	Adult 1st Floor	Building C	Standard inefficient units 3.0 gal/flush, pressurized	3	24	3	72	13680	630	
	Girls 2nd Floor	Building C	Standard inefficient units 3.0 gal/flush, pressurized	1.6	168	4	268.8	51072	2352	
	Boys 2nd Floor	Building C	Standard inefficient units 3.0 gal/flush, pressurized	1.6	42	4	67.2	12768	588	
	Adult 2nd Floor	Building C	Standard inefficient units 3.0 gal/flush, pressurized	3	24	1	72	13680	630	
	Girls 1st Floor	Building D	Standard inefficient units 3.0 gal/flush, pressurized	1.6	48	1	76.8	14592	672	
	Boys 1st Floor	Building D	Standard inefficient units 3.0 gal/flush, pressurized	1.6	12	1	19.2	3648	168	
	Womens 1st Floor	Administration Building	Standard inefficient units 3.0 gal/flush, pressurized	3	20	1	60	11400	525	
	Mens 1st Floor	Administration Building	Standard inefficient units 3.0 gal/flush, pressurized	3	5	1	15	2850	131.25	
	Unisex 2nd Floor	Administration Building	Standard inefficient units 3.0 gal/flush, pressurized	3	10	1	30	5700	262.5	
Toilet Total						55	2140.2	406638	18726.75	425364.75
Urinal	Boys 1st Floor	Building B	Standard inefficient units 1.6 gal/flush	1.6	144	3	230.4	43776	2016	
	Boys 2nd Floor	Building B	Standard inefficient units 1.6 gal/flush	1.6	144	3	230.4	43776	2016	
	Boys 1st Floor	Building C	Water efficient unit 0.125 gal/flush	0.125	126	3	15.75	2992.5	137.8125	
	Boys 2nd Floor	Building C	Standard inefficient units 1.6 gal/flush	1.6	126	3	201.6	38304	1764	
	Mens 1st Floor	Administration Building	Standard inefficient units 1.6 gal/flush	1.6	15	1	24	4560	210	
Urinal Total						13	702.15	133408.5	6143.8125	139552.3125
Faucet	1st Floor	Building A	Standard, inefficient 2.2 gpm	0.55	144	56	79.2	15048	693	
	Classrooms	Building A	5 min	2.2		3	33	6270	288.75	
	Girls 1st Floor	Building B	Standard, inefficient 2.2 gpm	0.55	192	3	105.6	20064	924	
	Boys 1st Floor	Building B	Standard, inefficient 2.2 gpm	0.55	192	3	105.6	20064	924	
	Adult 1st Floor	Building B	Standard, inefficient 2.2 gpm	0.55	32	1	17.6	3344	154	
	Girls 2nd Floor	Building B	Standard, inefficient 2.2 gpm	0.55	192	3	105.6	20064	924	
	Boys 2nd Floor	Building B	Standard, inefficient 2.2 gpm	0.55	192	3	105.6	20064	924	
	Adult 2nd Floor	Building B	Standard, inefficient 2.2 gpm	0.55	32	1	17.6	3344	154	
	Classrooms	Building B	5 min	2.2		8	88	16720	770	
	Girls 1st Floor	Building C	Water efficient faucet 1.5 gpm (15 sec)	0.375	168	2	63	11970	551.25	
	Boys 1st Floor	Building C	Water efficient faucet 1.5 gpm (15 sec)	0.375	168	2	63	11970	551.25	
	Adult 1st Floor	Building C	Standard, inefficient 2.2 gpm	0.55	24	1	13.2	2508	115.5	
	Girls 2nd Floor	Building C	Standard, inefficient 2.2 gpm	0.55	168	3	92.4	17556	808.5	
	Boys 2nd Floor	Building C	Standard, inefficient 2.2 gpm	0.55	168	3	92.4	17556	808.5	
	Adult 2nd Floor	Building C	Standard, inefficient 2.2 gpm	0.55	24	1	13.2	2508	115.5	
	Classrooms	Building C	5 min			7	77	14630	673.75	
	Girls 1st Floor	Building D	Standard, inefficient 2.2 gpm	0.55	48	1	26.4	5016	231	

Figure 48: Hokulani Existing Water Data[258]

[258] Made by Author.

Type	Location	Building	Description	G/use	Uses/day	Units	total G/d	Total g/yr Schooldays	Non-Schooldays at 5%	Total Water Use
	Boys 1st Floor	Building D	Standard, inefficient 2.2 gpm	0.55	48	1	26.4	5016	231	
	Womens 1st Floor	Administration Building	Standard, inefficient 2.2 gpm	0.55	20	1	11	2090	96.25	
	Mens 1st Floor	Administration Building	Standard, inefficient 2.2 gpm	0.55	20	1	11	2090	96.25	
	Unisex 2nd Floor	Administration Building	Standard, inefficient 2.2 gpm	0.55	16	1	8.8	1672	77	
Faucet Total						105	1155.6	219564	10111.5	229675.5
Shower	Girls 1st Floor	Building C	Water efficient showerhead 2.0 gpm 15 min/day			1	30	5700	262.5	
Shower Total						1	30	5700	262.5	5962.5
Indoor Total								765310.5	35244.5625	800555.0625
Water Fountain	Building A	Building A	Consumption: 1 qt/kid and 1/2 gal per adult				21	3990	183.75	
	Building B	Building B	Consumption: 1 qt/kid and 1/2 gal per adult				56	10640	490	
	Building C	Building C	Consumption: 1 qt/kid and 1/2 gal per adult				48	9120	420	
	Building D	Building D	Consumption: 1 qt/kid and 1/2 gal per adult				8	1520	70	
	Administration Buil	Administration Building	Consumption: 1 qt/kid and 1/2 gal per adult				7	1330	61.25	
Water Fountain Total								26600	1225	27825
Irrigation								69182.8	3459.2	
Irrigation Total								69182.8	3459.2	72642
Outdoor Total								95782.8	4684.2	100467
TOTALS								861093.3	39928.7625	
GRAND TOTAL									901022.0625	

Figure 49: Hokulani Existing Water Data[259]

[259] Made by Author.

9.6 Hokulani Water Efficiency Strategies

9.6.1 Indoor Water Efficiency Strategies

Hokulani uses a total of 1,188,010 gallons of water annually. Of this amount, 822,680 gallons are used for indoor water use. This accounts for almost 70% of total amount of water used by the school. The other 30% is dedicated to outdoor water use.

Toilets

Figure 50: Hokulani's Existing Toilets[260]

Hokulani currently uses standard inefficient flushometer toilets. Hokulani has a total of 55 toilets (6 are water efficient and 49 are standard inefficient units). The water efficient units use 1.28 gal/flush while the standard toilets use between 1.6 and 3 gal/flush. The toilets use a total of 425,364 gallons of water annually. The toilets in Hokulani are floor mounted toilets. Hokulani restrooms can be retrofitted to contain flushometer low volume flush toilets. Low volume flushometer toilets use no more than 1.28 gpf. Replacing the standard inefficient units with water efficient units would save 106,109 gallons of water annually. The toilets would cost $329.40 each while the flushometer would cost $199.45. Replacing all the standard inefficient toilets would cost $25,913.65. Both the toilet bowl and flushometer can be bought at multiple stores in Hawaii. Since these toilets are virtually the same in terms of appearance, operation, and maintenance this is the best choice for the school as well as the students. Abrasive or chemical cleaners should not be used to clean flushometers as they may dull the luster and attack the chrome or decorative

[260] Taken by Author.

finish. Only mild soap and water should be used then wiped dry with a clean towel or cloth. The inside of the bowl can be cleaned with powder, liquid or gel cleaner. The outside of the bowl can be cleaned using a disinfectant/detergent cleaner, mixed either in a spray bottle or in a bucket, spray down or wipe all hard surfaces outside the bowl. Specifications for the floor mounted, low volume flushometer toilets are located in the Appendix.

Urinals

Figure 51: Hokulani's Existing Urinals[261]

Hokulani also uses standard inefficient urinals. Hokulani has a total of 13 wall mounted urinals (3 water efficient and 10 standard inefficient units). The water efficient units use 0.125 gal/flush while the standard units use 1.6 gal/flush. The urinals use a total of 139,552 gallons annually. These urinals can be replaced with low volume flow urinals. These urinals use 0.125 gpf. The water efficient urinals will save 125,763 gallons of water annually. These urinals cost $171.60 each. Replacing all 10 standard inefficient units will cost $1,716. These urinals will be different in appearance as they will be smaller than the urinals that are currently in the school. Since the toilets will be of different size, repair work will need to be performed when replacing the units. The urinals should be cleaned regularly. The inside of the urinal can be cleaned with powder, liquid or gel cleaner while the outside of the urinal can be cleaned using a disinfectant/detergent cleanser that is mixed in a spray bottle or in a bucket. Wall finishes should be updated or made to match in areas that are left exposed in areas that we previously covered. Specifications for the wall mounted urinals are located in the Appendix.

Faucets

[261] Taken by Author.

Figure 52: Hokulani's Existing Faucet[262]

The school also uses standard water faucets that use about 2.2 gpm. There are 105 faucet units (4 water efficient units and 101 standard, inefficient units) within the school. This study makes the assumption that students use about 0.55 gallons per use for standard, inefficient units and 0.375 gallons per use for water efficient units in which students wash their hands for about 15 seconds. The water efficient units use 1.5 gpm while the standard inefficient units use 2.2 gpm. The faucets use a total of 229,675 gallons annually. All the faucets should be replaced with water efficient faucets. The faucets selected use 0.5 gpm. Assuming the students wash their hands for about 15 seconds, a water efficient faucet that uses 0.5 gpm will use 0.1 gallon per use. Changing out inefficient units for water efficient units will save 184,002 gallons of water a year. This is an 80% water savings for faucets within the school. These units cost $145 each and will cost $15,225 to replace all 105 units. The faucets can be easily installed by removing the old faucet, dropping the new faucet in from the top and using quick spin nuts to secure the faucet in place. These faucets can be bought at multiple stores in Hawaii. Since the students are still young, I chose to keep the manual faucets so they can be easily turned on and off and decreases the chances of children using them as a toy or breaking them.

Shower

[262] Taken by Author.

Figure 53: Hokulani's Existing Shower[263]

The school has one shower in building C. This shower has a water efficient showerhead that uses 2.0 gpm. The assumption is made that the shower is used for 15 minutes per day. The shower uses 5,962 gallons of water annually. Since the shower already has a water efficient showerhead I chose not to make any changes to the shower.

Replacing standard fixtures with water efficient fixtures will save 416,877 gallons a year. This is a 52% reduction in water use. Hokulani is currently charged $3.76 for every 1,000 gallons of water used. Reducing their water consumption by 416,877 gallons will result in a cost savings of $1,567.45 a year.

9.6.2 Outdoor Water Efficiency Strategies

Water Fountain

[263] Taken by Author.

Figure 54: Hokulani's Existing Water Fountains[264]

Hokulani also has about 10 water fountains. The assumption is made that students consume 1 quart each while adults consume ½ a gallon a day. The water fountains account for 27,825 gallons of water annually. The water fountains will be kept the same since the amount of water that they consume is minimal.

Irrigation

Hokulani currently doesn't have an irrigation system. Since Hokulani is a relatively small campus, it does not have a large amount of outdoor landscaped area. Hokulani currently uses about 69,182 gallons a year for outdoor irrigation. The amount of water that is used for landscaping can be reduced by using water conservation strategies as well as supplementing potable water with recycled water.

In the redesign of Hokulani's landscape, the areas available for landscaping are divided into separate hydro zones. Native and non-invasive vegetation will be used as it has the best chance of surviving and thriving in the landscape and will rely mostly on natural rainfall.

Water saving irrigation components such as high efficiency nozzles will be incorporated so that the amount of water that is wasted when irrigating is reduced. Smart controllers will also be used to schedule irrigation based on evapotranspiration and weather conditions. Smart controllers will create an intelligent irrigation schedule that is right for the local landscape by downloading information such as temperature, wind speed and soil moisture to adjust run time and days to water. Although the landscaping will be equipped with smart controllers, maintenance workers will still need to check on plants to make sure they are not being over or under watered. If the plants are not thriving, adjustments can be made to the smart controllers to provide more or less irrigation.

Reducing Hokulani's irrigation by 30% will save 21,792 gallons of water a year. Incorporating smart water controllers and designing the landscape in hydro zones will decrease

[264] Taken by Author.

outdoor water use. This will save $81.93 a year for outdoor efficiency and conservation strategies.

Hokulani's total water savings from efficiency measures will reduce water use by 438,669 gallons a year. This is a 49% decrease in water use annually. Reducing water use by 438.669 gallons a year saves $1,649.40. In addition to water savings, Hokulani is also reducing the strain of water transport and extraction. The water savings is based only on water use bill and does not take into account sewer charges which would result in additional savings. The efficiency and conservation measures will save water for future generations.

Type	Location	Building	Description	G/use	Uses/day	Units	total G/d	Total g/yr Schooldays	Total g/year Non-Schooldays at 5%	Total Annual	previous water use	water savings	% saved
Toilet	1st Floor	Building A	Water efficient unit 1.28 gal/flush	1.28	144	12	184.32	35020.8	1612.8				
	Girls 1st Floor	Building B	Water efficient unit 1.28 gal/flush	1.28	192	5	245.76	46694.4	2150.4				
	Boys 1st Floor	Building B	Water efficient unit 1.28 gal/flush	1.28	48	4	61.44	11673.6	537.6				
	Adult 1st Floor	Building B	Water efficient unit 1.28 gal/flush	1.28	32	1	40.96	7782.4	358.4				
	Girls 2nd Floor	Building B	Water efficient unit 1.28 gal/flush	1.28	192	5	245.76	46694.4	2150.4				
	Boys 2nd Floor	Building B	Water efficient unit 1.28 gal/flush	1.28	48	4	61.44	11673.6	537.6				
	Adult 2nd Floor	Building B	Water efficient unit 1.28 gal/flush	1.28	32	1	40.96	7782.4	358.4				
	Girls 1st Floor	Building C	Water efficient unit 1.28 gal/flush	1.28	168	3	215.04	40857.6	1881.6				
	Boys 1st Floor	Building C	Water efficient unit 1.28 gal/flush	1.28	42	3	53.76	10214.4	470.4				
	Adult 1st Floor	Building C	Water efficient unit 1.28 gal/flush	1.28	24	3	30.72	5836.8	268.8				
	Girls 2nd Floor	Building C	Water efficient unit 1.28 gal/flush	1.28	168	4	215.04	40857.6	1881.6				
	Boys 2nd Floor	Building C	Water efficient unit 1.28 gal/flush	1.28	42	4	53.76	10214.4	470.4				
	Adult 2nd Floor	Building C	Water efficient unit 1.28 gal/flush	1.28	24	1	30.72	5836.8	268.8				
	Girls 1st Floor	Building D	Water efficient unit 1.28 gal/flush	1.28	48	1	61.44	11673.6	537.6				
	Boys 1st Floor	Building D	Water efficient unit 1.28 gal/flush	1.28	12	1	15.36	2918.4	134.4				
	Womens 1st Floor	Administration Building	Water efficient unit 1.28 gal/flush	1.28	20	1	25.6	4864	224				
	Mens 1st Floor	Administration Building	Water efficient unit 1.28 gal/flush	1.28	5	1	6.4	1216	56				
	Unisex 2nd Floor	Administration Building	Water efficient unit 1.28 gal/flush	1.28	10	1	12.8	2432	112				
Toilet Total						55	1601.28	304243.2	14011.2	318254.4	425364.8	107110.4	25%
Urinal	Boys 1st Floor	Building B	Water efficient unit 0.125 gal/flush	0.125	144	3	18	3420	157.5				
	Boys 2nd Floor	Building B	Water efficient unit 0.125 gal/flush	0.125	144	3	18	3420	157.5				
	Boys 1st Floor	Building C	Water efficient unit 0.125 gal/flush	0.125	126	3	15.75	2992.5	137.8125				
	Boys 2nd Floor	Building C	Water efficient unit 0.125 gal/flush	0.125	126	3	15.75	2992.5	137.8125				
	Mens 1st Floor	Administration Building	Water efficient unit 0.125 gal/flush	0.125	15	1	1.875	356.25	16.40625				
Urinal Total						13	69.375	13181.25	607.03125	13788.28125	139552.3	125764.0188	90%
Faucet	1st Floor	Building A	Water efficient faucet 0.5 gpm (15 sec)	0.1	144	56	14.4	2736	126				
	Classrooms	Building A	5 min	0.5		3	7.5	1425	65.625				
	Girls 1st Floor	Building B	Water efficient faucet 0.5 gpm (15 sec)	0.1	192	3	19.2	3648	168				
	Boys 1st Floor	Building B	Water efficient faucet 0.5 gpm (15 sec)	0.1	192	3	19.2	3648	168				
	Adult 1st Floor	Building B	Water efficient faucet 0.5 gpm (15 sec)	0.1	32	1	3.2	608	28				
	Girls 2nd Floor	Building B	Water efficient faucet 0.5 gpm (15 sec)	0.1	192	3	19.2	3648	168				
	Boys 2nd Floor	Building B	Water efficient faucet 0.5 gpm (15 sec)	0.1	192	3	19.2	3648	168				
	Adult 2nd Floor	Building B	Water efficient faucet 0.5 gpm (15 sec)	0.1	32	1	3.2	608	28				
	Classrooms	Building B	5 min	0.5		8	20	3800	175				
	Girls 1st Floor	Building C	Water efficient faucet 1.5 gpm (15 sec)	0.1	168	2	16.8	3192	147				
	Boys 1st Floor	Building C	Water efficient faucet 1.5 gpm (15 sec)	0.1	168	2	16.8	3192	147				
	Adult 1st Floor	Building C	Water efficient faucet 0.5 gpm (15 sec)	0.1	24	1	2.4	456	21				
	Girls 2nd Floor	Building C	Water efficient faucet 0.5 gpm (15 sec)	0.1	168	3	16.8	3192	147				
	Boys 2nd Floor	Building C	Water efficient faucet 0.5 gpm (15 sec)	0.1	168	3	16.8	3192	147				
	Adult 2nd Floor	Building C	Water efficient faucet 0.5 gpm (15 sec)	0.1	24	1	2.4	456	21				
	Classrooms	Building C	5 min	0.5		7	17.5	3325	153.125				
	Girls 1st Floor	Building D	Water efficient faucet 0.5 gpm (15 sec)	0.1	48	1	4.8	912	42				
	Boys 1st Floor	Building D	Water efficient faucet 0.5 gpm (15 sec)	0.1	48	1	4.8	912	42				
	Womens 1st Floor	Administration Building	Water efficient faucet 0.5 gpm (15 sec)	0.1	20	1	2	380	17.5				
	Mens 1st Floor	Administration Building	Water efficient faucet 0.5 gpm (15 sec)	0.1	20	1	2	380	17.5				
	Unisex 2nd Floor	Administration Building	Water efficient faucet 0.5 gpm (15 sec)	0.1	16	1	1.6	304	14				
Faucet Total						105	229.8	43662	2010.75	45672.75	229675.5	184002.75	80%

Figure 55: Hokulani Water Efficiency Data[265]

[265] Made by Author.

Type	Location	Building	Description	G/use	Uses/day	Units	total G/d	Total g/yr Schooldays	Total g/year Non-Schooldays at 5%	Total Annual	previous water use	water savings	% saved
Shower	Girls 1st Floor	Building C	Water efficient showerhead 2.0 gpm 15 min/day			1	30	5700	262.5				
Shower Total						1	30	5700	262.5	5962.5	5962.5	0	0%
Indoor Total								366786.45	16891.48125	383677.9313	800555.1	416877.1688	52%
Water Fountain		Building A	Consumption: 1 qt/kid and 1/2 gal per adult				21	3990	183.75				
		Building B	Consumption: 1 qt/kid and 1/2 gal per adult				56	10640	490				
		Building C	Consumption: 1 qt/kid and 1/2 gal per adult				48	9120	420				
		Building D	Consumption: 1 qt/kid and 1/2 gal per adult				8	1520	70				
		Administration Building	Consumption: 1 qt/kid and 1/2 gal per adult				7	1330	61.25				
Water Fountain Total								26600	1225	27825	27825	0	0%
Irrigation								48427.96	2421.44				
Irrigation Total								48427.96	2421.44	50849.4	72642	21792.6	30%
Outdoor Total								75027.96	3646.44	78674.4	100467	21792.6	22%
TOTALS								441814.41	20537.92125	462352.3313	901022.1	438669.7688	49%
								Grand Total:	462352.3313				

Assumptions:
Building A: 72 students; 50:50 boy:girl
Building A: 6 adults
Building B: 96 students upstairs/96 downstairs; 50:50 boy:girl
Building B: 16 adults; 8 per floor
Building C: 84 students upstairs/ 84 downstairs; 50:50 boy:girl
Building C: 12 adults; 6 per floor
Building D: 24 students; 50:50 boy:girl
Building D: 4 adults
Administration Building: 10 adults 1st floor; 4 Adults 2nd Floor
each girl: 4 toilet flushes; each boy: 1 toilet = 3 urinal
standard showerhead 2.5 gpm
watersense showerhead 2.0 gpm or less
standard bathroom faucet 2.2 gpm
watersense faucet no more than 1.5 gpm
190 schooldays, 175 off days use 5% of schooldays
wash hands: 30 sec

Figure 56: Hokulani Water Efficiency Data Cont.[266]

[266] Made by Author.

9.7 Water Reuse Strategies

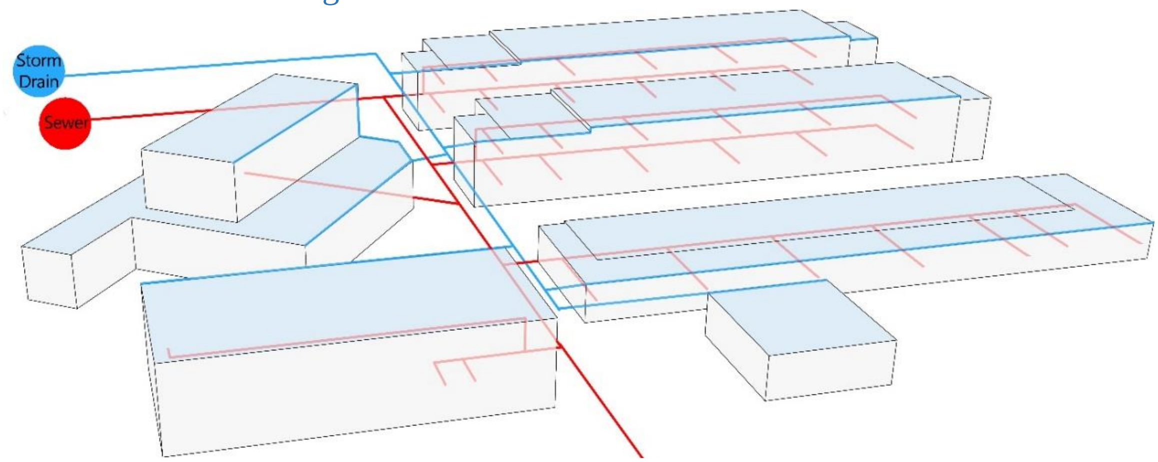


Figure 57: Current Water Use Diagram[267]

Figure 57 shows a diagram of Hokulani's current water use. Hokulani currently does not reuse any water. Hokulani receives potable water that is used for consumption, toilets, faucets, urinals, showers and irrigation. The red line denotes water that has been used within the building and the blue line represents rainwater that flows from the rooftops of the buildings. Rainfall from the rooftops is not harvested and currently flows into the storm drain.

Hokulani receives an average of 34.46 inches of rain annually. Monthly rainfall data is shown in Table 4 and Figure 58. From the monthly rainfall data, the amount of water that is able to be harvested can be found. The following equation was used to determine the amount of rainfall that is able to be harvested throughout the year:

Monthly Harvested Rainfall = (monthly rainfall x roof area x 0.623) x 2/3

The monthly amount of rainfall that can be harvested can be found by multiplying the monthly rainfall by the available roof area time the rainfall coefficient (0.623). This is then multiplied by 2/3 to account for evaporation and first flush.

Month	Average Monthly Rainfall (in.)
January	3.92
February	2.99
March	4.49
April	2.52
May	1.85
June	1.5
July	2.01
August	1.54
September	1.73
October	3.35
November	3.93
December	4.63

Table 4: Average Monthly Rainfall

[267] Made by Author.

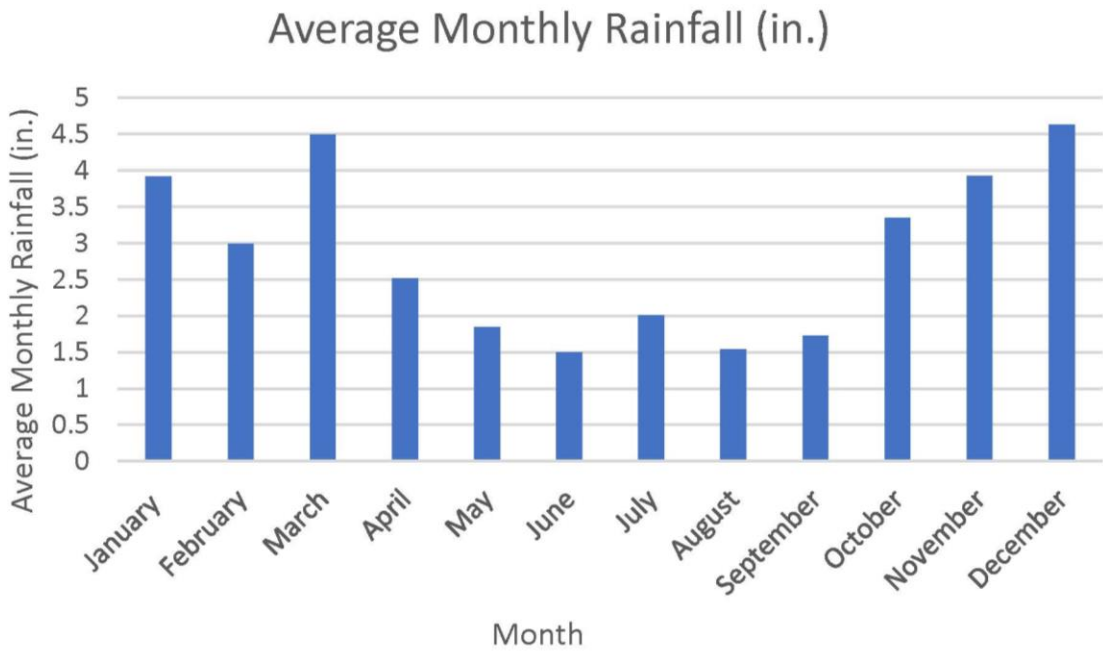


Figure 58: Average Monthly Rainfall[268]

Building	Area (sq. ft.)
Building A	7142
Building B	7062
Building C	7062
Building D	6528
Building G	1195
Administration Building	4003
Total	32,992

Table 5: Total Roof Area[269]

[268] Made by Author.
[269] Made by Author.

	Harvested Water Potential	Water Used
January	53,714	45,333
February	40,971	64,691
March	61,525	55,827
April	34,531	103,172
May	25,350	92,333
June	20,554	81,333
July	27,542	57,000
August	21,102	70,000
September	23,706	92,000
October	45,904	83,000
November	53,852	87,000
December	63,443	69,333
Annual	472,194	901,022

Table 6: Harvested Water Potential[270]

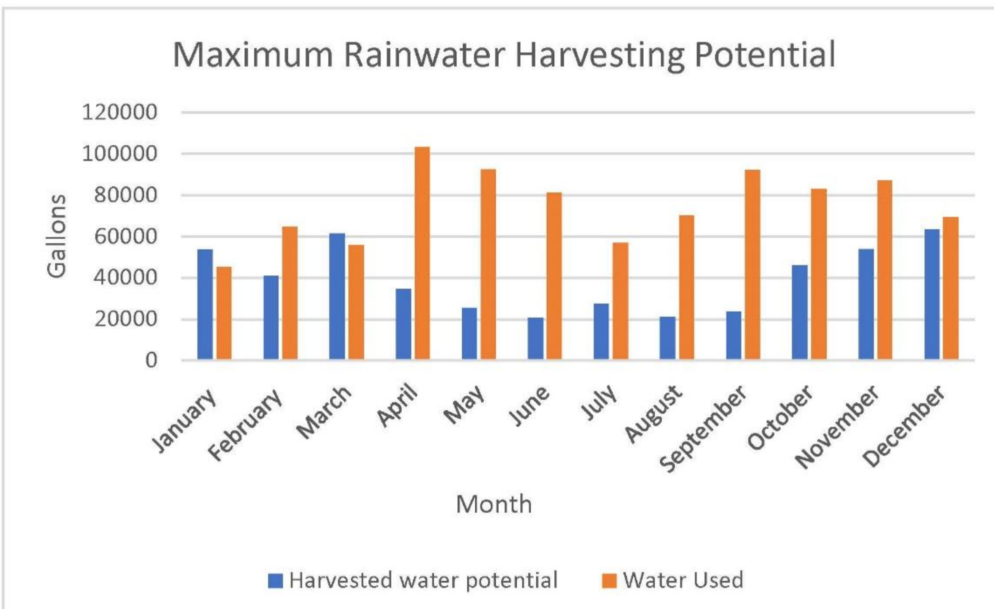


Figure 59: Rainwater Harvesting Potential[271]

In Figure 59 we can see that the water used is usually higher than the harvested water potential. This means that all the harvested water should be collected and recycled to obtain the most potable water reduction and savings.

[270] Made by Author.
[271] Made by Author.

Figure 60: Landscape Area[272]

The landscape can be divided into seven landscape areas. Area 1 is the main entry area. This area has the peace garden that was planted by the students and features a number of native plants. These plants have low maintenance and low irrigation demand. Area 2 is the space behind Building G. This space currently has a playground that the students use. Area 3 is the space between Building A and Building B. This area is currently made up of turf grass and a few trees. This area is not used often and has a high irrigation demand. Area 4 is the space between Building B and Building C. This space also contains turf grass and trees and is not used regularly by the students. Area 5 is the area behind Building C. This area has another playground that is used by the students. This area also has a small area of unused space that has turf grass and remains relatively underutilized. The last area is area 6. This area is underutilized and has turf grass. This area has a high irrigation demand and is not used by the students.

[272] Made by Author.

Figure 61: Proposed Landscape Plan[273]

[273] Made by Author.

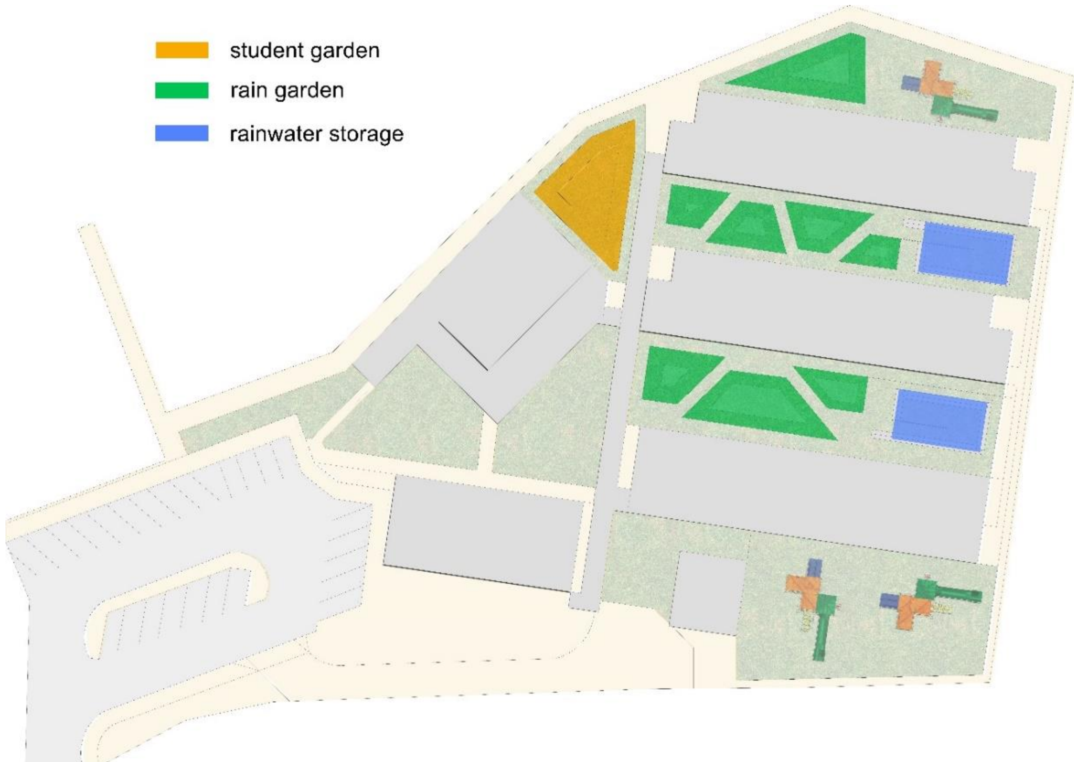
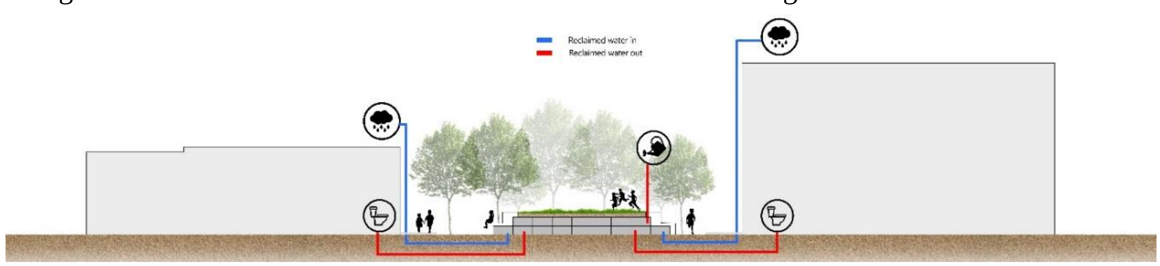


Figure 62: Hokulani Landscape Functions[274]

Figure 61 and Figure 62 shows the proposed landscape plan and the landscape functions of each of the areas. Area 1 will be kept the same. Since the students have participated in building and planting this Peace Garden it is something that they should take ownership and pride in. This is something that connects them to the school and gives them pride. The Peace Garden also is planted with native plants. Since native plants are acclimated to the climate they are more likely to thrive and use less rainwater since they are adapted to the natural rainfall of the area.

Area 2 is occupied by a playground. This area is currently utilized by the students and should be kept relatively the same. The area around the playground is planted with turf grass. The turf grass can be replaced with El Toro Zoysia which has good drought tolerance and adapts well to high heat. This will allow for a recreational area while also using less water.

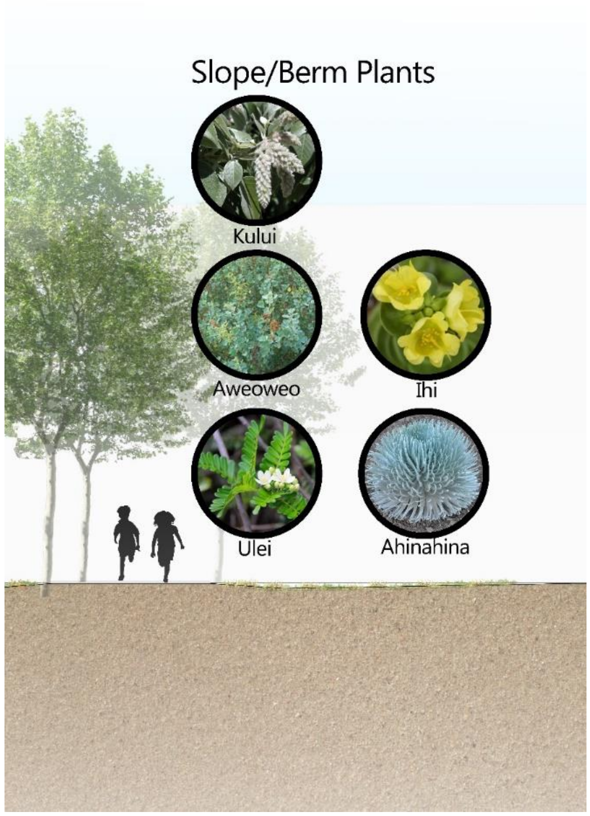


Area 3 will contain a water storage area that encourages students to use the space. There will be a grassed plaza that houses the underground modular storage system underneath. The plaza encourages students to use the area and can be planted with El Toro Zoysia as well. Area 3 will also contain 3 rain gardens. The rain gardens will receive overflow water from the cisterns

[274] Made by Author.

and will be planted with native plants. The rain gardens will aid in infiltration and filtration and provide a learning area for students. Each of the rain gardens will be a different depth and will flow in a sequence if one overflows. The rain gardens will also be planted with native plants and allow students to learn more about the native plants of the area.

Figure 63: Section A[275]



[275] Made by Author.

Figure 64: Section A1 -Rain Garden 1[276]

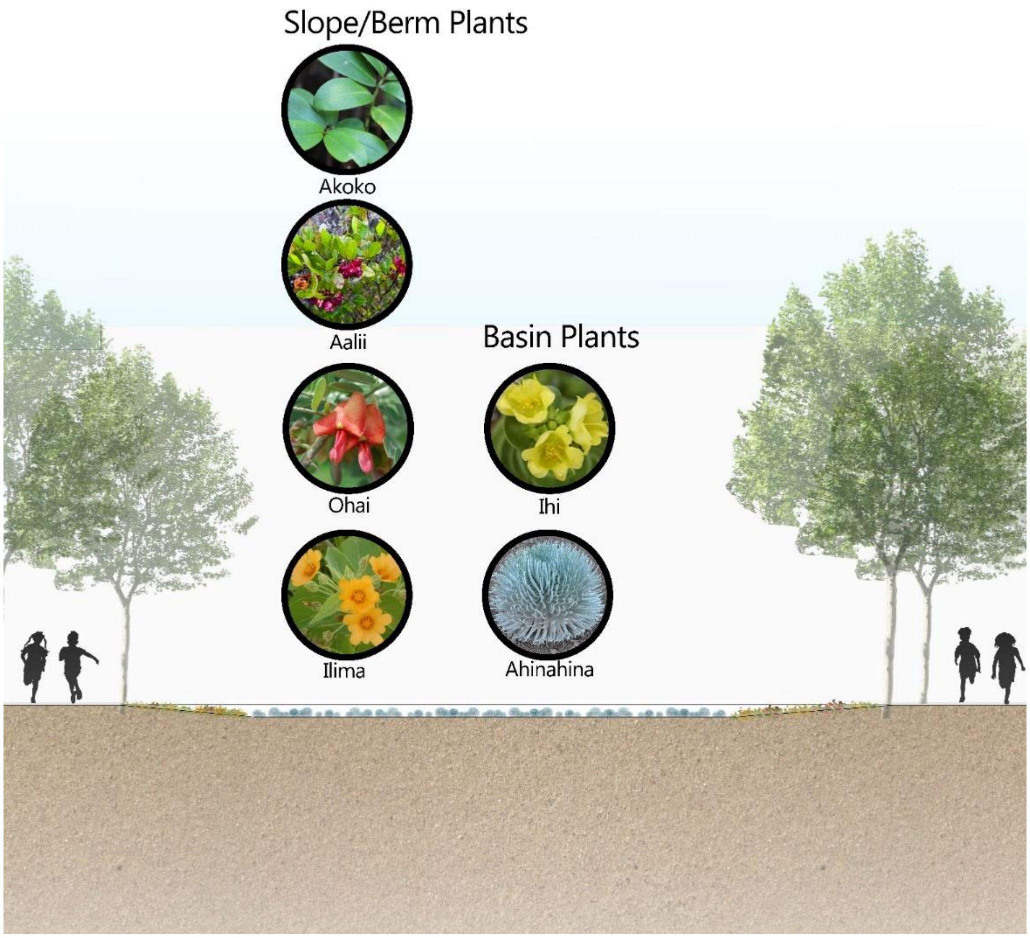


Figure 65: Section A2-Rain Garden 2[277]

[276] Made by Author.
[277] Made by Author.

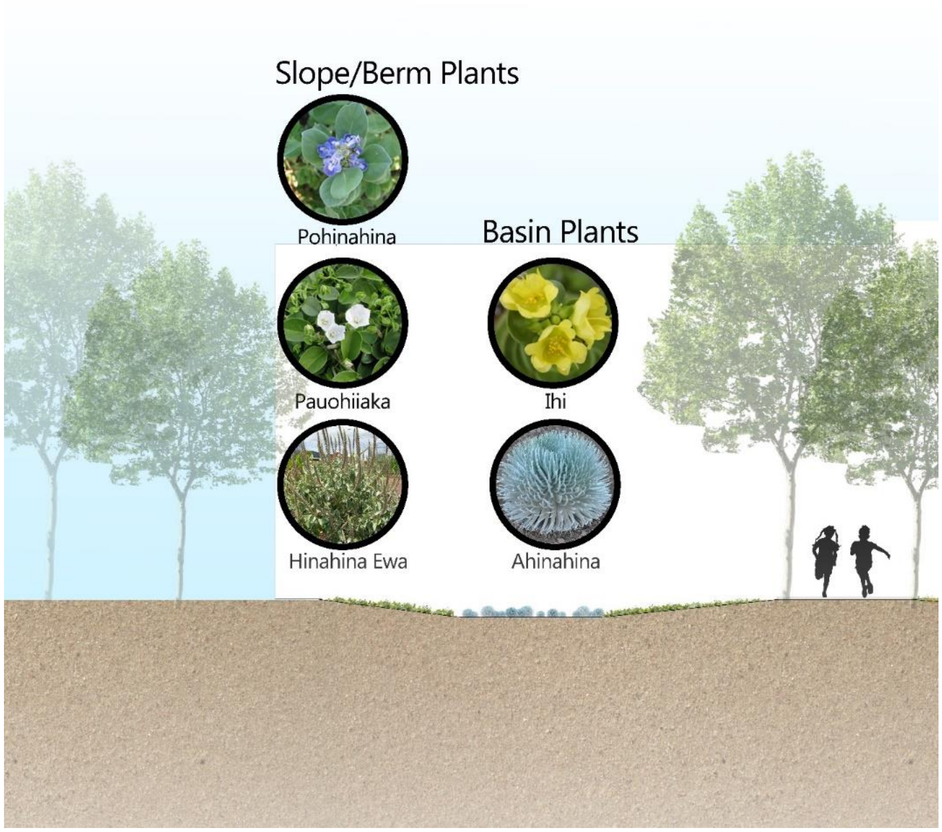


Figure 66: Section A3-Rain Garden 3[278]

Area 4 will also contain a water storage area. Area 4 will have a storage area of 155 units. This will be able to hold 9,207 gallons of water. This water can then be used for flushing toilets or for irrigation. The plaza play space will be located on top of the storage area. This area will be similar to area 3. Area 4 will have 4 rain gardens. Each will have a different depth and will be planted with different plants. The plant list for plants that can be used in each of the rain gardens will be located in the Appendix.

278 Made by Author.

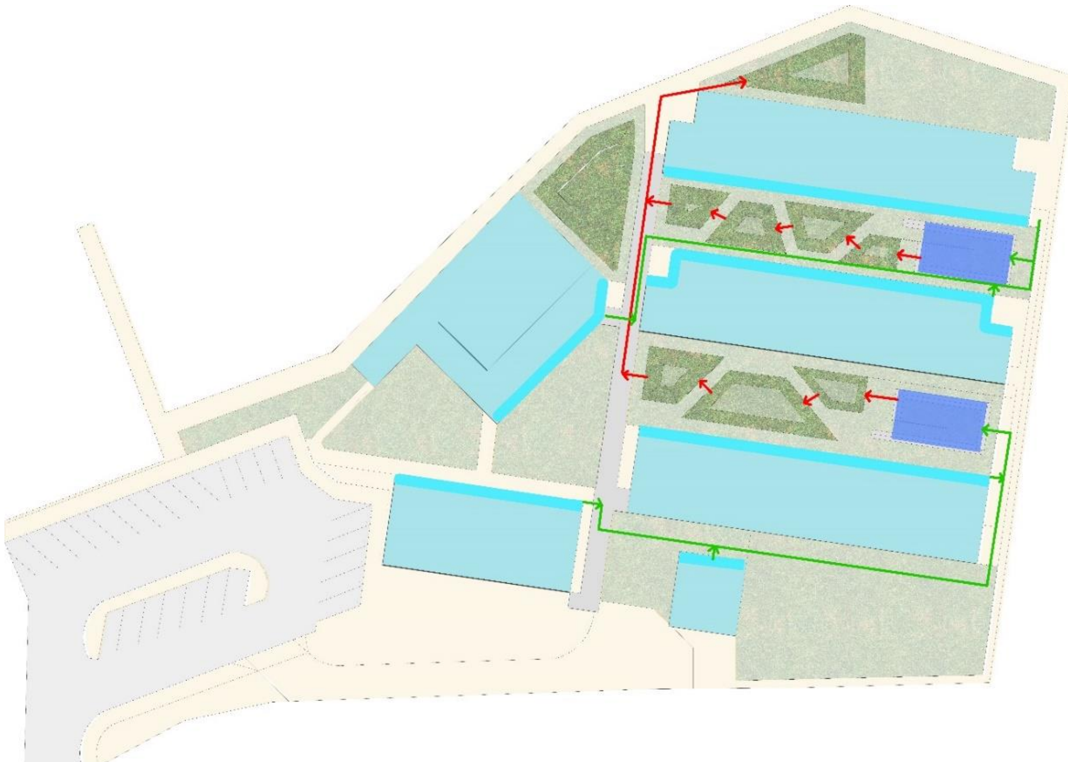


Figure 67: Hokulani Landscape Overflow Diagram[279]

Area 5 currently has a playground that is used by the students. Area 5 will also contain another rain garden that will be the overflow point for the rain gardens in area 3 and 4. Since this is the lowest point on the campus the water can be directed here by gravity. Water will flow from the roofs of the buildings into the water storage tanks. In the event that the tanks reach their capacity, the water will then be directed to the rain gardens. If the rain gardens are flooded and have reached their capacity the water will then flow to the rain garden in area 5. If the rain garden in area 5 is flooded the water will then be directed to a storm drain.

Area 6 will be used as a student garden. The garden will be planted with native plants and will be watered by the students from the rain catchment storage. This will allow students to better understand how the water system works and give them a sense of ownership. This will encourage students to use water wisely and hopefully help to develop responsible habits that they can use at home and in their lives after they leave the school.

[279] Made by Author.

Figure 68: EcoBloc Max Modular Water Storage System[280]

The design proposes that Hokulani Elementary School uses a modular underground cistern system. This will allow for the system to be upgraded if its needs expand. Using a modular system makes it easier to add or subtract units based on the amount of water usage. The storage system should be based on the amount of water that can be collected and is used. The design proposes storing 18,414 gallons of water. The EcoBloc Maxx Modular Water Storage System design allows for flexible construction and unlimited capacity. A single unit costs $64.90 and the primary module holds 59.4 gallons and is 31.5" x 31.5" x 13.8".[281] The system will sit beneath the plaza area that children are able to play on.

The water storage system should also include a first flush diverter. The first flush of water from the roof can contain bacteria as well as sediments and residues that are undesirable to have inside the water storage system. A first flush diverter will allow the first flow of water to be diverted from the water storage system. The first flush diverter should be installed at all of the downpipes that supply water to the tank. About 12.5 gallons should be diverted for a minimally polluted roof of 1,000 sq. ft. and 50 gallons should be diverted for a heavily polluted roof of 1,000 sq. ft.[282] A minimally polluted roof would be in an open field with no trees or bird droppings while a substantially polluted roof would have leaves, debris, bird droppings, etc.

In addition, pumps should be incorporated into the modular cistern system. Pumps will be needed to pump water from the cistern to the toilets in the various buildings and for water that is needed for irrigation. The pump should be able to be automatically activated to pump water to toilets as well as accessing the potable water supply if there is no longer water in the cistern. Since the cistern is underground, the pumps will need to pump water up for the water to flow to the toilets and other indoor fixtures that can use recycled water.

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[280] "Graf EcoBloc Maxx Modular Water Storage System." Rainwater Collection and Stormwater Management. Accessed February 22, 2017. http://www.rainharvest.com/graf-ecobloc-maxx-modular-water-storage-system.asp.

[281] "Graf EcoBloc Maxx Modular Water Storage System." Rainwater Collection and Stormwater Management. Accessed February 22, 2017. http://www.rainharvest.com/graf-ecobloc-maxx-modular-water-storage-system.asp.

[282] "Rain Harvesting Pty Downspout First Flush Diverter." Rainwater Collection and Stormwater Management. Accessed March 14, 2017. http://www.rainharvest.com/rain-harvesting-pty-downspout-first-flush-diverter.asp.

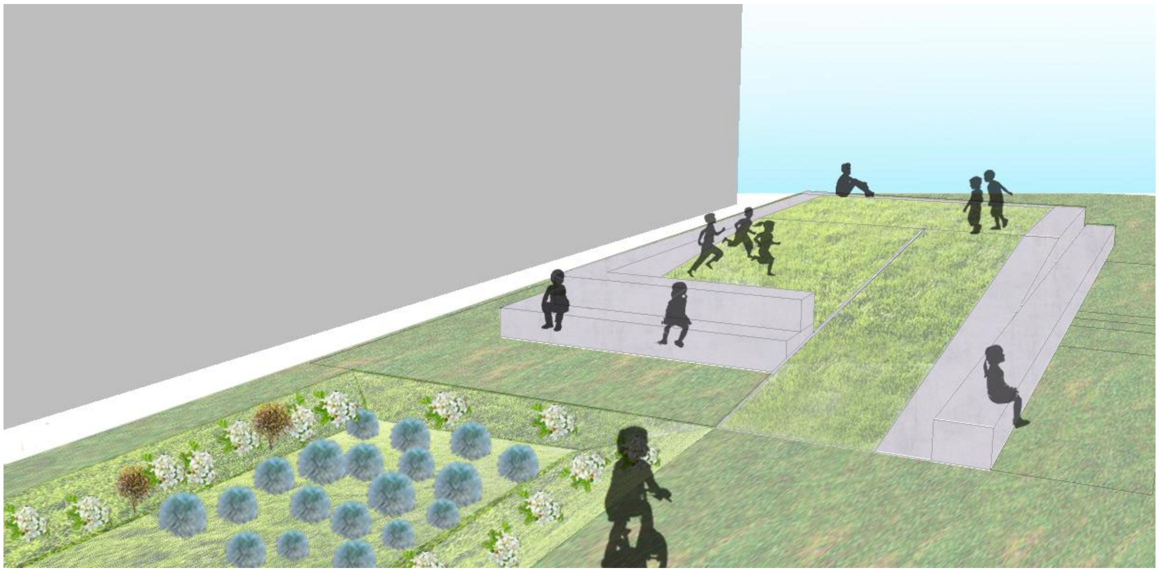

Figure 69: Area 3 Rendering[283]

The 18,414-gallon storage area should be able to hold all the rainwater from the rooftops of Hokulani. The rainfall will provide 236,098 gallons of recycled water a year. This will provide 63% of the non-potable water that is used within the school. This accounts for toilets and irrigation. Using recycled water and using efficiency measures will reduce Hokulani's potable water use by 75%. This is a water savings of 673,093 gallons a year. That is a total savings of $2,530 a year.

9.8 Conclusion

The design proposes efficiency, conservation and reuse strategies that will save water. The changes made will save Hokulani Elementary School up to 673,093 gallons of water a year. Not only will these strategies help to save money, but they will also conserve water for the future generations. In addition, the less water that needs to be transported to the site means the less amount of water that needs to be transported and extracted. The rainwater that is collected from the roofs of the buildings will be reused within the building to flush toilets, as well as being used for irrigation. This reduces the amount of potable water that is used but also reduces the amount of water that will flow into the storm drains. This will reduce the amount of pollutant that will enter water bodies. The rain gardens will be areas where extra water can be directed if there is an overflow. The rain gardens will allow for infiltration and filtration. The rain gardens will also encourage students to learn more about the water cycle and how water can be reused. The rain gardens can be used within the school curriculum as well as offering learning opportunities about the native plants within the rain gardens.

[283] Made by Author.

10. Conclusion

As we begin to face issues such as climate change and sea level rise in Hawaii, the need to use resources wisely is increasingly important. The increase in impervious surfaces, due to urbanization, has begun to affect water movement and the quality of water. Although we live on an island surrounded by water, we still face water issues and must begin to make changes to conserve the resources that we have. Over the coming years, Hawaii will face water problems associated with scarcity, pollution, climate change as well sea level rise.

Water conservation, efficiency, and reuse strategies are vital to reducing water use. These strategies can result in economic savings, environmental benefits and a reduction in water use. This also means that there will be more water for future generations. The amount of water that is available for us will remain the same while the population continues to increase. If we continue using water wastefully, we will soon run out of a resource that is so precious to everyday life.

Water efficiency strategies include metering, water efficient appliances and fixtures. These strategies can result in a large amount of water savings that can then be translated into cost savings. These strategies require more initial investment but can result in a large amount of cost savings. Switching out old inefficient fixtures can result in a large amount of water and cost savings thus conserving water.

Water conservation strategies can be divided into two categories. The two categories are indoor and outdoor strategies. Indoor strategies are simple behavior changes such as taking shorter showers and turning off the faucet when it is not in use. Outdoor strategies focus on landscaping, such as setting up an efficient watering schedule and xeriscaping.

Water reuse strategies can be used indoors and outdoors. Water reuse strategies include water reuse for storm water, greywater and black water. Currently incorporating greywater and black water reuse into schools is difficult due to the strict standards in water reuse guidelines especially due to health concerns. While it is possible this paper chose to only incorporate storm water reuse into the guidelines and design portion. Water reuse strategies include water catchment and different reuse and low impact development strategies. Water reuse is an opportunity to satisfy water demands with non-potable water. In addition to offsetting potable water demands, water reuse can also save electricity and prevent pollution. Incorporating water catchment and low impact development strategies can reduce the amount of potable water being used as well as providing learning opportunities for the students. Since many reuse strategies can be observed, students can learn from these systems and begin to take these principles home with them.

The paper outlines a number of different strategies that can be used in all types of projects but mainly focusing on schools. While not all the strategies are suitable for all locations, the design strategies section outlines different strategies as well as a brief description of the strategy and their costs, benefits, drawbacks, and maintenance. This serves as a tool to outline different strategies that are currently available and gives a quick overview to help decide which strategies can be used in different projects.

The design guidelines section provides an outline that can serve as a tool for the DOE. The design guidelines set goals to achieve in water reduction. The guidelines outline ways to achieve water reduction in each category and specifically outlines how the goals can be met in a step by step approach that is easy to follow. This is a user-friendly guideline that administrators can use to implement water efficiency, conservation, reuse strategies within schools.

The design portion looks at Hokulani Elementary School which is located in Honolulu, Hawaii. The design project showed and applied different strategies that can be used to reduce water use in other school in Hawaii. The design for Hokulani School used a number of strategies that can be used to reduce water as well as providing a learning experience for students. The design incorporated efficiency as well as reuse strategies for the school to reduce its overall water use. The design resulted in an overall reduction of 75% and a cost savings of $2,350 a year.

The thesis looks at strategies specifically for school on Oahu but the impacts can be experienced around the world. Reducing water use is not something that should only be limited to schools but to everyone in general as the impacts of water scarcity are felt around the world. Water is a finite resource that is limited especially since we live on an island. By taking steps to improve efficiency, reuse and conserve water use we can in turn begin to conserve water for the future generations. In addition, using less water also means using less electricity which in turn results in a decrease in greenhouse gases. By conserving water and improving efficiency we can begin to mitigate these problems. In addition, water reduction can save money and electricity. The thesis provides a broad overview of efficiency, conservation and reuse strategies while the guidelines provides an outline to direct readers on how these strategies can be applied within their own projects. The thesis seeks to influence water reuse in schools which will in turn influence the future generations to protect and preserve the water resources for the generations to come.

List of Figures

List of Tables

Appendix

Low Flow Urinal

Low Flow Flushometer

Low Flow Faucet

Plant List

Trees

Loulu	*Pritchardia spp.*
‘Ohi’a ‘Ai	*Syzygium malaccense*
Koa	*Acacia koa*
‘Ohia	*Metrosideros polymorpha*

Shrubs

Alahe’e	*Psydrax odorata*
Hapu’u	*Cibotium sp.*
‘Aali’i	*Dodonaea viscosa*
Naupaka kuahiwi	*Scaevola guadichaudiana*
Na’u	*Gardenia brighamii*

Groundcover

El Toro Zoysia

Rain Garden Plants

Slope/berm plants

‘Ulei	*Osteomeles anthyllidifolia*
‘Aweoweo	*Chenopodium oahuense*
Kulu’i	*Nototrichium sandwicense*
‘Ilima	*Sida fallax*
‘Ohai	*Sesbania tomentosa*
‘Aali’i	*Dodonaea viscosa*
‘Akoko	*Chamaesyce celastroides*
Pohinahina	*Vitex rotundifolia*
Pa’u o hi’iaka	*Jacquemontia ovalifolia subsp. sandwicensis*
Hinahina Ewa	*Achyranthes splendens rotundata*
Naio Papa	*Myoporum sandwicense*

Basin Plants

‘Ahinahina	*Artemisia mauiensis*
‘Ihi	*Portulaca molokiniensis*
Uki	*Machaerina angustifolia*
‘Uki’uki	*Dianella sandwicensis*
Loulu	*Pritchardia sp.*

Student Garden Plants

Kalo	*Colocasia esculenta*
‘Ulu	*Artocarpus altilis*

‘Uala	*Ipomoea batatas*
Mai’a	*Musa acuminta*
Ko	*Saccharum officinarum*

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